With or Without: an Assessment of Brazil's More Doctors Program on Population Health

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AN ASSESSMENT OF BRAZIL'S MORE DOCTORS PROGRAM ON POPULATION HEALTH

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Abstract

Renewed commitment to the Universal Health Coverage agenda reinvigorated interest in primary care. Yet, there is limited evidence on the performance of community-level targeting methods used in large-scale primary care programs. Empirical evidence from developing countries on the contribution of primary care on population health over time relies primarily on ecological studies. This dissertation addresses these knowledge gaps by providing a comprehensive assessment of Brazil's More Doctors Program (MDP).

We, first, examine the beneficiary targeting performance of the MDP in the period between 2013-2017 (Chapter II). We find that almost 70% of municipalities with vulnerability designation enrolled in the MDP from 2013 to 2017; whereas 33% of municipalities that joined MDP in this period did not match any of the vulnerability criteria. We show that vulnerable municipalities that did not receive MDP physicians had the highest poverty rate and lowest physician availability in primary care settings.

Next, we evaluate the impact of MDP on hospitalizations due to a set of conditions considered to be avoidable with timely and appropriate provision of primary care services. We combine coarsened exact matching and different-in-difference methods to construct valid counterfactual estimates using a municipal-aggregated dataset covering the period from 2009 to 2017. We show that the MDP led to 10.04 (95%CI: -19.16, -0.92) fewer hospitalizations per 100,000 municipal inhabitants for

avoidable cardiovascular conditions (Chapter III). The estimated MDP coefficient for avoidable hospitalizations among children and adolescents under 20 years of age was 1.84 (95%CI: -5.34, 1.66), suggesting that the MDP did not reduce the avoidable hospitalizations for this age group (Chapter IV). The program contributed to the narrowing of urban-rural disparities, with an estimated MDP coefficient of -7.43 (95%CI: -13.20, -1.65) for rural municipalities, compared to 1.23 (CI95%: 3.16,5.61) for urban areas.

The dissertation findings highlight that targeting methods used in large-scale primary care programs have important implications for the extent to which they are able to allocate program resources to their target populations. They demonstrate the complexities in translating increased investment in primary care. They further underscore that a sizable infusion of resources in primary care in underserved settings can improve population health.

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List of Acronyms

BAHD: Brazil Atlas of Human Development

CEM: Coarsened Exact Matching

CVD: Cardiovascular Disease

DAB-SAS: Primary Care Department of the Secretariat of Health Assistance

DID: Difference-in-difference

FHS: Family Health Strategy

GDP: Gross Domestic Product

IBGE: Brazilian Institute of Geography and Statistics

ICD-10: International Classification of Diseases, Tenth Revision

IMR: Infant Mortality Rate

MHDI: Municipal Human Development Index

HIS: Hospital Information System

MDP: More Doctors Program

MPS: *Médicos pelo Brasil*

MOH: Ministry of Health

NCD: Non-communicable Diseases

NFM: National Front of Mayors

NIP: National Immunization Program

ORS: Oral rehydration salts

SD: Standard deviation

SDG: Sustainable Development Goals

SGTES: Secretariat of Labor Management and Health Education

SIAB: Information System on Primary Care

UHC: Universal Health Coverage

UHS: Unified Health System

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Chapter I:

Introduction

In 2015, all 193 countries of the United Nations signed a commitment to achieve universal health coverage (UHC) as an integral component of the Sustainable Development Goals (SDG) agenda (United Nations 2015). Yet, many developing countries face substantial challenges in their UHC aspirations (Das *et al.* 2008; Shetty 2011; WHO 2018a). About 400 million people, primarily from low- and middle-income countries, lack access to essential health care services (WHO and World Bank 2015). Globally, an estimated 60% of deaths occur due to poor quality of care for health conditions that are potentially preventable with timely and effective health care (Kruk *et al.* 2018). Out-of-pocket expenditures are among the leading causes of impoverishment (Xu *et al.* 2003; Xu *et al.* 2007; Verguet *et al.* 2017), with 100 million people risk being pushed into extreme poverty in the face of debilitating health expenditures (WHO and World Bank 2015).

The global momentum around the UHC agenda has reinvigorated interest in strengthening primary care (WHO 2018a). Previous works highlight that primary care offers a cost-effective strategy to address population health needs by providing greater access to care (Shi 2012), offering a broad range of preventive care services, improving the coordination of care across different levels of the health system (Kringos *et al.* 2010), enhancing patient-focused care over time (Starfield 1994; Starfield 1998; WHO 2018a; WHO 2018b), and contributing to the narrowing of health disparities (Macinko and Lima-Costa 2012).

Despite the policy interest and mounting evidence on the contributions of primary care to population health in low- and middle-income countries, there are important knowledge gaps (Briggs 2001; Hone *et al.* 2018). There is limited evidence on the performance of community-level targeting methods used in large-scale primary care programs to identify vulnerable communities, even though these methods are shown to impact the extent to which target communities benefit from program resources (Sabates-Wheeler *et al.* 2015; Devereux *et al.* 2017). Most empirical studies that examine the relationship between primary care and population in developing countries rely on ecological study designs, with limited rigorous evidence focusing on the impact of primary care on population health over time (Macinko *et al.* 2009). Furthermore, we know relatively little about the relationship between strengthening primary care and the prevention and management of non-communicable diseases (NCDs) in low- and middle-income countries, while approximately 85% of premature deaths due to NCDs annually occur in these settings (Beaglehole *et al.* 2008; WHO 2018c).

Motivated by these gaps in the extant literature, this dissertation examines the extent to which increased investment in primary care in traditionally underserved communities impacts population health in the context of Brazil. We chose Brazil for three reasons. First, over the last three decades, Brazil has made progress towards achieving UHC goals through its Unified Health System (UHS). Established in 1990, the UHS has been shown to improve health system performance in Brazil (Castro *et al.* 2019). Second, the Family Health Strategy (FHS) is the main platform for progress towards UHC goals within the UHS organization. Today, the FHS is the world's largest community-based primary care program providing care to more than 122 million people (Andrade *et al.* 2018). Third, the focus of this dissertation, the More Doctors Program (MDP), was introduced in 2013 in order to address geographic disparities in primary care physician availability in the context of the FHS. At its height, the MDP was the world's largest government-led initiative that recruited primary care physicians, both domestic and international, to work solely in primary care settings within communities that typically faced difficulties recruiting and retaining physicians.

1.2. Background on primary care

In the last 40 years, primary health care has been conceptualized and described in various ways. In this dissertation, I adopt the definition of primary health care proposed by the WHO as a holistic approach to health and well-being that centers around empowering people (i.e., individuals, families and communities) by focusing on their needs and preferences throughout their life course. This approach entails the provision of a comprehensive set of primary care services ranging from health promotion and prevention to curative, rehabilitative and palliative care (WHO 2018a). By definition, primary health care promotes person-focused care over time that goes beyond merely addressing disease etiology and emphasizes consideration of social, economic and environmental determinants of health (Starfield 2011).

Several features of primary care distinguish it from secondary and tertiary care. Primary care necessitates a complex set of interactions between patients, providers and other levels of the health system, as well as intersectoral collaboration, rather than merely managing clinical tasks (Starfield 1998; Hone *et al.* 2018). It serves as the first point of entry to the health system before patients seek care elsewhere (Starfield 1998). Primary care professionals provide a comprehensive range of health services to address the most common health conditions (rather than very specific diseases), often with ill-defined clinical symptoms (Finley *et al.* 2018). They diagnose and manage diseases in the context that they occur, better positioning them to recognize the social and environmental factors surrounding their patients (Starfield 1998). Primary care underscores the importance of continuity of care over time in order to accrue information about patients and encourages the transfer of this information between primary care providers and specialists (Starfield 1998; Starfield 2011). Primary care on its own is not a panacea, however, it should be complemented with strong coordination and integration across different levels of care and foster links with communities (Starfield 2012; Hone *et al.* 2018; WHO 2018b).

A substantial body of research consistently demonstrated the contribution of primary care to population health in developed and developing countries (Rohde *et al.* 2008; WHO 2018b). Several literature reviews showed that primary care has been associated with gains in population health (Macinko *et al.* 2009; Kringos *et al.* 2010), greater efficiency in service delivery (Wilson and Childs 2002; Kringos *et al.* 2010), better quality of care (Kruk *et al.* 2008; Friedberg *et al.* 2010), and reductions in health care costs (Kringos *et al.* 2010). Strengthening primary care has also been shown to alleviate inequitable access to care and reduce health disparities (Shi 2012). More recently, Hone *et al.* (2018) suggested that strengthening primary care and achieving broader development goals beyond health can contribute to SDG goals beyond health.

Several literature reviews highlight, however, that there are important research gaps. The choice of targeting method used in social programs can have important consequences for the extent to which these programs can reach their target populations (Devereux *et al.* 2017). Two recent literature reviews highlight that most studies that examine the performance of beneficiary targeting methods in social programs focus on individual-level approaches (e.g. means testing) rather than community-level methods (Sabates-Wheeler *et al.* 2015; Devereux *et al.* 2017). Even though many countries use community-level methods to target beneficiaries in large-scale health programs, empirical evidence in this literature comes primarily from poverty alleviation programs (Devereux *et al.* 2017).

Another knowledge gap relates to empirical evidence from developing countries on the contribution of primary care to population health over time. Recently, two papers concluded that most studies that examine the impact of strengthening primary care on population health in developing countries rely on ecological study designs (Macinko *et al.* 2009; Shi 2012). Many analyses report findings from small-scale primary care interventions, with very little evidence from large-scale investments in primary care (Macinko *et al.* 2009). Moreover, we know relatively little about the impact of interventions focusing on strengthening primary care on the prevention and management of NCDs in low- and middle-income countries, even though these countries bear an important share of the NCD burden (Beaglehole *et al.* 2008; WHO 2018c).

1.3. Primary care in the Brazilian context: Family Health Strategy

The 1988 Brazilian Constitution established health as a fundamental right of all citizens and tasked the state to ensure UHC. The Constitutional mandate for achieving UHC goals was operationalized through the UHS. Established in 1990, the UHS has contributed to health system performance over time (Castro *et al.* 2019). Between 1990 and 2018, the infant mortality rate (IMR) declined from 52.5 to 13.2 per 1,000 live births (World Bank 2019) and stunting prevalence among children under 5 years of age declined substantially (Victora *et al.* 2011). Socioeconomic and geographic disparities in health outcomes narrowed, though stark disparities in access to care continue to disproportionally affect vulnerable populations (Massuda *et al.* 2018; Castro *et al.* 2019).

Since its launch in 1994, the FHS has become the centerpiece of efforts towards achieving UHC goals within the organization of the UHS (Andrade *et al.* 2018). The FHS approach has four core tenets. First, it serves as the entry point to the health system. Each household is assigned to a multi-professional FHS team comprised of physicians, nurses and community health workers. Each FHS team serves approximately 3,500 people in non-overlapping areas. Second, FHS teams provide a comprehensive range of preventive care services free-of-charge. These services include not only typical primary health care activities, mostly targeting children and women, but also those focusing on the control of communicable and chronic diseases, including hypertension, and diabetes, and health promotion and education. Third, the FHS approach underscores whole-person care rather than disease-focused care through its emphasis on understanding the social, economic and environmental conditions surrounding the households, and communities. FHS teams regularly visits the households in their assigned lists regardless of their health needs and serves as a bridge between households and other social and education programs. Fourth, FHS teams are responsible for the coordination of care through referrals to specialists and emergency care in hospitals.

Most empirical evidence shows that investment in primary care in Brazil has had profound implications on population health. Using state-level data from 1990 to 2002, Macinko *et al.* (2006) found that a 10% increase in FHS coverage was associated with a 4.5% reduction in IMR, partly due to a reduction in diarrhea-related mortality. Macinko *et al.* (2007) also reported reductions in IMR, post-neonatal mortality and mortality attributable to diarrhea based on data from 557 microregions between 1999 and 2004, though the authors did not find evidence that the FHS contributed to reductions in neonatal mortality in this period. Macinko *et al.* (2007) further concluded that the FHS expansion may have contributed to reducing of regional disparities in infant deaths, with more pronounced correlations between FHS coverage and diarrhea-related and post-neonatal deaths in areas that bear a large burden of these deaths.

Findings from subsequent studies were in congruence with these earlier works. Aquino and colleagues (2009) found a statistically significant inverse relationship between the FHS expansion and IMR using municipal-level data covering the period between 1996 and 2004. The authors also showed that the effect of the FHS was greater in municipalities with lower levels of socioeconomic development. Rasella *et al.* (2010) showed that the high levels of FHS scale-up were associated with a 13% reduction in mortality rates among children under 5 years of age between 2000 and 2005, with approximately 31% and 19% reduction from deaths attributable to diarrheal diseases and lower respiratory infections, respectively. Rocha and Soares (2010) found similar reductions in IMR, with the effects of FHS increasing over time. More recently, Russo *et al.* (2019) also showed that increases in primary care physician density was inversely associated with infant deaths. In their analysis, the authors took into account the availability of FHS team member other than physicians (i.e. nurses, midwives and community health workers) in an area, though they did not discuss the potential ways through which collaboration between different FHS professionals may influence primary care provision.

Within the highly decentralized governance structure of Brazil, municipalities play a key role in the adoption and implementation of the FHS services. The FHS scaled up rapidly, with the proportion of population covered increasing from 0.06 in 1998 to 0.81 in 2012 (Andrade *et al.* 2018). The initial expansion until 2002 favored poorer and traditionally underserved communities in the Northeastern states (Rocha and Soares 2009). However, as documented by Andrade and colleagues (2018), there were stark differences in the levels of FHS coverage by geographic regions and population size in 2012. One possible explanation highlighted consistently in previous studies was the highly skewed distribution of physicians toward municipalities with higher levels of socioeconomic development, particularly in the South and Southeast regions (Scheffer *et al.* 2013; Andrade *et al.* 2018).

The focus of this dissertation, the More Doctors Program, was introduced in 2013 with the objective of bolstering primary care physician availability within the FHS. Through the MDP, Brazil embarked on a large-scale primary care program, which entailed the recruitment of domestic and foreign physicians to work in traditionally underserved communities that faced challenges in attracting health professionals, among other investments to strengthen primary care provision (Santos *et al.* 2017). At its height in 2015, almost 15 thousand physicians were contracted by the MDP, making it the largest government-led initiative in the world to bolster primary care physician availability in disadvantaged communities (Silva *et al.* 2018).

Several design features of the MDP enable us to advance our understanding of the ways in which strengthening primary care can contribute to population health. The MDP recruits were required to work only in primary care settings within the organization of the FHS. The MDP only recruited physicians who had prior training in family medicine. All MDP physicians were required to attend medical training programs at regular intervals during their tenure in Brazil. Unlike other physicians in Brazil who are employed directly by municipal governments, the MDP physicians were contracted directly with the MOH for a period of three years with the possibility of renewal. All 5,570 municipalities were eligible to join the program, though the MOH used an explicitly defined set of rules to inform the distribution of MDP physicians, prioritizing communities with lower levels of socioeconomic development and high levels of poverty, and those located in the traditionally underserved North and Northeast regions.

The next section discusses the potential mechanisms through which these program features may have contributed to population health.

1.4. Hypotheses about the impact of MDP on population health

In this dissertation, I hypothesize that the MDP may have led to improvements in population health by strengthening the core features of primary care provision in Brazil, leading to changes in health behaviors among citizens, and alleviating the adverse effects of geographic disparities between communities.

First, increases in primary care physician availability may have increased the likelihood that patients seek care from the FHS team to which they are assigned before going to other providers. Earlier studies demonstrate that an inverse relationship between increased interactions with primary care physicians and hospitalizations (PCPCC 2019), emergency department visit for non-urgent care (Bradley *et al.* 2018), and hospital re-admission rates (Chetty *et al.* 2010; Farrel *et al.* 2015). In Brazil, the MDP may have increased the number of primary care visits as a proxy for first-contact care, because patients who were not covered by the FHS teams might have now gained access to the FHS health professionals since the MDP physicians contributed to the formation of new FHS teams.

Second, the greater availability of primary care physicians may have enhanced the continuity of care over time. The ways in which primary care is organized and delivered have been shown to improve the likelihood that a patient seeks care from the same provider over time (Starfield 2012). Patients with a usual source of care are more likely to receive better quality of care (Romano *et al.* 2015), report higher satisfaction with health services (Reddy *et al.* 2015) and incur lower health expenditures (Fan *et al.* 2004; Hussey *et al.* 2014; Bazemore *et al.* 2018). Conversely, high staff turnover is associated with a lower probability of receiving preventive care services, including childhood immunizations and preventive screening (Plomondon *et al.* 2007), and weaker coordination of care between levels of care in patient referrals (Juliani *et al.* 2017). Increases in the continuity of care have further been linked to reductions in the utilization of specialist care (Nyweide *et al.* 2013), reductions in hospitalizations and emergency department use (Pourat *et al.* 2015), as well as reductions in medical errors (Gandhi *et al.* 2006). In Brazil, Dourado and colleagues recently showed that in areas with greater FHS coverage, a greater proportion of the population reported having a usual source of care, particularly in the poorest regions in the North and Northeast (Dourado *et al.* 2015). The MDP may have improved the continuity of care over time, because MDP physicians were contracted by the MOH to work in the same municipality for a period of at least three years as part of the FHS teams, with the potential to renew their contract.

Third, the probability of receiving preventive healthcare services may have increased with the greater availability of primary care physicians. An important feature of primary care is its ability to offer a wide range of preventive care services that aim to tackle the social, economic and environmental determinants of health (Starfield 1998; WHO 2010) to avoid unnecessary referrals to specialist care (Starfield 2012) and to manage NCDs (Rothman and Wagner 2003; Dennis *et al.* 2008; Reynolds *et al.* 2018). For instance, primary care professionals can perform cardiovascular risk assessments (Abegunde *et al.* 2012), manage chronic conditions (e.g. hypertension and diabetes), provide tobacco cessation and nutrition counseling and organize health education activities (Taggart *et al.* 2012). In Brazil, staff shortages have been linked to increased workload among FHS professionals (de Lima Trindade *et al.* 2014), which may hinder the FHS teams' capacity to provide all of the preventive care activities for which they are responsible. None of MDP's design features specifically target NCDs and we do not expect a change in the scope of preventive care provided in primary care settings. However, through the infusion of new primary care physicians, the workload of the existing FHS team members might have eased. If the FHS teams had more staff capacity/time, then it is plausible that the probability of receiving preventive healthcare services increased with the MDP. Alternatively, patients with no prior FHS coverage might have now been assigned to the newly formed FHS teams, which may also lead to increases in the likelihood that they receive preventive care.

Fourth, the coordination of care across different levels of the health system may have improved with an increase in the number of primary care physicians. In many settings, primary care professionals serve as the gatekeepers of the health system (Kringos *et al.* 2010*)*. They diagnose the most common conditions (Finley *et al.* 2018) and refer patients to other levels of care. Greater access to primary care has been linked with better coordination of care (Penm *et al.* 2017) and lower re-hospitalization rates (Misky *et al.* 2010), though evidence remains mixed in terms of the effects of gatekeeping on health service utilization and health care costs (Delnoji *et al.* 2000; Garrido *et al.* 2010). In Brazil, the FHS teams do not have a formal gatekeeping function; patients can seek care in secondary and tertiary hospitals without a medical referral from their primary care physicians. However, the MDP may have led to increases in medical referrals to other providers, if primary care physicians determine that their patients require specialist and emergency care.

Fifth, greater availability of primary care physicians may have led to behavior change among patients. As discussed earlier, the FHS teams provide a range of health promotion and education activities depending on local needs. An increase in the number of primary care physicians may have increased the frequency of health education and promotion activities leading to behavioral change among patients, as was shown in other settings (Rana *et al.* 2009; Taggart *et al.* 2012; Panda *et al.* 2015). In this case, it is plausible to observe that the impacts of the MDP on patient behaviors may have endured even after the program physicians left their posts.

Additionally, the MDP may have reduced some of the adverse effects of geographic disparities. Primary care is less capital intensive compared to specialist care, giving primary care professionals more flexibility to tackle the diverse health needs of the population and to address social determinants of health (Starfield 1998). In Brazil, the FHS has been linked with alleviating geographic disparities in access to (Andrade *et al.* 2018) and utilization of healthcare services (Gragnolati *et al.* 2013), though important inequities remain (Castro *et al.* 2019). Given that the MDP aims to improve physician availability in underserved communities, we expect the impact of the program to be more pronounced in areas that typically had difficulties in attracting and retaining health professionals (e.g. rural municipalities).

1.5. Overview of dissertation

This dissertation provides a comprehensive analysis of the impact of the MDP by deploying spatial and quasi-experimental methods. Chapter 2 investigates the performance of community targeting in the MDP in the first four years of its implementation from 2013 to 2017. Chapters 3 and 4 evaluate the impact of MDP on hospitalizations due to a set of conditions considered to be avoidable by the provision of timely and appropriate primary care services.

Chapter 2 examines the performance of community targeting in MDP in the period from 2013 to 2017. Recently, two literature reviews highlighted that the consequences of community-level targeting methods used in social programs (e.g. poverty alleviation initiatives, school feeding programs, nutrition interventions) for the extent to which they successfully allocate program resources to their target populations is an understudied area of research (Sabates-Wheeler *et al.* 2015; Devereux *et al.* 2017). Many health programs rely on community-level methods to identify their target communities. Yet, empirical evidence comes primarily from poverty alleviation programs (Devereux *et al.* 2017). Chapter 2 addresses these gaps by studying the community-level targeting performance of the MDP. We used a conceptual framework that considered the program enrollment and vulnerability designation status of municipalities in each year of program implementation, allowing us to track the performance of community targeting over time. To conduct this analysis, we built a longitudinal dataset by merging municipal-aggregated information from several publicly available sources. We calculated the rate at which target municipalities were enrolled in the MDP in a given year. We derived the prevalence of two different versions of mistargeting (i.e. under-coverage and leakage). We further investigated municipal-level characteristics by enrollment and vulnerability dimensions. Chapter 2 further informed the study designs deployed in Chapters 3 and 4.

Next, we turned our attention to evaluating the impact of MDP on hospitalizations over time (Chapters 3 and 4). Developed in the early 1990s to assess the health system performance of the United States (Billings *et al.* 1993), the concept of avoidable hospitalizations is used to describe a set of health conditions for which the likelihood of hospitalizations could be reduced by the provision of timely and effective ambulatory care. Hospitalizations for these conditions are considered to be avoidable through the prevention of disease onset, the effective management of chronic conditions or the control of an acute episodic illness (Billing *et al.* 1993). Today, many high-income countries, including the United States, the United Kingdom, Canada, and Spain, track hospitalizations due to avoidable conditions to monitor their health system performance. In 2008, the Brazilian MOH published a list of health conditions for which hospitalizations can be avoided by providing primary care services given the unique contextual factors in Brazil, considering a review of existing literature from other settings, as well as consultations with different stakeholders in the health system. (Alfradique *et al.* 2009). The Brazilian list differs from others in its emphasis on infectious diseases. In both studies, we selected health conditions from this list and earlier studies and extracted municipal-aggregated patient records from the Hospital Information System (HIS) of the UHS by International Classification of Diseases, Tenth Revision (ICD-10). Additional data sources included the MOH, the IBGE, and the Brazilian Regulatory Agency.

The HIS is a national database that collates patient records from all municipalities in Brazil for all hospitalizations financed by the HIS, including those in the public sector, private and non-profit facilities. Upon admission, health professionals assign ICD-10 codes to each case depending on the diagnosis. Following the discharge from the hospital, medical archivists review medical charts and make a determination to agree or revise the ICD-10 code assigned in admission. The HIS is used for reimbursement purposes and reportedly captures an estimated 70% of all hospitalizations that occur every year (Sgambatti *et al.* 2015). It is used frequently in studies focusing on hospitalizations, including the relationship between the FHS expansion and avoidable hospitalizations (Bastos *et al.* 2017). Studies evaluating the data quality of the HIS concluded that it is a reliable dataset for secondary data analysis (Mathias *et al.* 1998; Bittencourt *et al.* 2008; Sgambatti *et al.* 2015), though we cannot rule out possible under-reporting or coding errors in administrative data (Bittencourt *et al.* 2006). To the best of our knowledge, there were no changes in the hospital reimbursement regulations during our study period.

Chapter 3 studies the impact of MDP on avoidable hospitalizations for cardiovascular conditions. Going beyond the scope of earlier works (Fontes *et al.* 2018), this study contributes to a more in-depth assessment of the impact of MDP by examining the impact of MDP on cardiovascular conditions - cerebrovascular disease, heart failure, and hypertension. Combined, these conditions represent the leading cause of death in Brazil and their burden is more pronounced in poorer regions (Schmidt *et al.* 2011; Victora *et al.* 2011). The study design allowed us to parse out the effects of the program over time. We explored the differences in the impact of the MDP between urban and rural municipalities. By doing so, this analysis shed light on whether efforts to strengthen primary care can lead to improvements in the management of cardiovascular conditions, particularly in underserved settings and highlighted the complexities involved in the implementation of large-scale primary care programs.

Chapter 4 investigates the impact of MDP on hospitalizations for children and adolescents under 20 years of age. We focused on this age group because the expansion of primary care services prior to the MDP has been shown to be more pronounced younger patients (Rocha and Soares 2010). We explored the impact of MDP on hospitalizations due to avoidable conditions, including asthma, infectious gastroenteritis, and pneumonia. We further examined whether the number of primary care consultations for children and adolescents was greater in municipalities where MDP physicians were serving than in non-MDP municipalities. Similar to Chapter 3, this study assessed whether investing in primary care contributed to the narrowing of urban-rural disparities in hospitalization rates. By doing so, this analysis provided new evidence to the literature on the impact of primary care on reducing urban-rural disparities.

Methodologically, chapters 3 and 4 complement each other. Both studies rely on quasi-experimental designs that incorporate coarsened exact matching and difference-in-difference methods for quasi-experimental thought experiments. For these analyses, we aim to construct valid estimates of counterfactual municipalities to ascertain how hospitalizations due to avoidable causes would have changed in the MDP municipalities in the absence of the program. We used coarsened exact matching to reduce imbalances in the empirical distribution of observable characteristics between treatment and control municipalities. The coarsened exact matching method allowed us to leverage our contextual knowledge on the program implementation, and the criteria used by the MOH to distribute program resources. By using coarsened exact matching, we were also able to retain study samples that are highly representative of the Brazilian population. In both studies, we defined treatment municipalities as those that had at least one MDP physician working in the community, and control municipalities as those that did not have any MDP physician throughout the study period. Our results were robust to several robustness checks.

Chapter 5 summarizes the findings from the three studies and discusses the policy implications of the findings and avenues for further research.

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Chapter II:

Assessing the performance of beneficiary targeting in Brazil's More Doctors Program

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Abstract

Introduction: Half of the world's population resides in rural communities, but only about a quarter of the global health professionals are deployed in these areas. To address imbalances in the geographic distribution of health workers, many countries employ strategies that rest on the use of an explicitly defined set of criteria to identify underserved communities. Yet, we know relatively little about the performance of community-level targeting in large-scale health programs. To address this gap, we examine the performance of community targeting in the More Doctors Program (MDP).

Data and Methods: Our analysis covers all 5,570 municipalities in the period between 2013-2017 using publicly available data. To evaluate targeting performance, we first calculate the rate at which vulnerable municipalities enrolled in the MDP. Next, we consider two types of mistargeting: (i) proportion of vulnerable municipalities that did not have any MDP physicians, and (ii) proportion of MDP enrollees that did not fit the vulnerability criteria.

Results: We found that almost 70% of municipalities that met the vulnerability criteria received at least one MDP physician between 2013 and 2017; whereas approximately 33% of municipalities that received MDP physicians did not match any of the vulnerability criteria. Municipalities with higher levels of socioeconomic development, supply of hospital beds and greater physician availability were more likely to receive MDP physicians despite not meeting any of the vulnerability criteria. Conversely, vulnerable municipalities that did not receive any MDP physicians had the highest poverty rate and lowest primary care physician availability. These municipalities were also smaller and more sparsely populated.

Conclusions: Our results suggest that the MDP faced substantial challenges in beneficiary targeting. They highlight that policymakers who consider using community-level targeting approaches in large-scale health programs should carefully consider barriers that hinder access to program benefits among vulnerable communities.

2.1. Introduction

Expanding equitable access to primary care is a priority in many low- and middle-income countries that seek to achieve Universal Health Coverage (UHC) (WHO 2018). Strong primary care systems are associated with improvements in population health, better quality of health services, and reductions in socioeconomic inequities in access to care (Macinko *et al.* 2003; Macinko *et al.* 2009; Kruk *et al.* 2010; Shi 2012; Starfield 2012; Kringos *et al.* 2013; Hone *et al.* 2017). Access to a trained health workforce is crucial to ensure effective health service coverage. Yet, only about a quarter of the global health workforce work in rural areas, even though half of the world's population resides in rural settings (Scheil-Adlung 2015).

Many countries rely on explicitly defined criteria to identify underserved communities in health programs aiming to alleviate imbalances in the distribution of the health workforce (OECD 2016). In the United States, the Health Professional Shortage Area designation is assigned using a composite score calculated based on healthcare service provider density, level of poverty, infant mortality rate and the age structure of each community (HRSA 2014). This designation is subsequently used for the recruitment of foreign physicians through visa waiver programs (Goodfellow *et al.* 2016). In Australia, communities with a shortage of medical practitioners are classified as the Distribution Priority Areas based on their demographic and socioeconomic status, population size and measures of geographic remoteness (Australian Government Department of Health 2019a). Foreign-trained general practitioners are obligated to serve at least 10 years in these communities (Australian Government Department of Health 2019b). In Canada, international medical graduates can join return-of-service programs that require them to work in underserved provinces in exchange for receiving residency training in the country (OECD 2016). Criteria used to define underserviced communities in Canadian provinces consider physician to population ratios, demographic and socioeconomic status and geographic accessibility (Ontario Ministry of Health Ministry of Long-Term Care 2019). While many health programs rely on criteria-based methods, there is little evidence on the consequences of these methods for the extent to which these programs are able to allocate their resources to target communities.

An extensive body of literature examines the impact of methods that are used in social programs (e.g. poverty alleviation initiatives, school feeding programs, nutrition interventions) to identify beneficiaries on the targeting performance (Coady *et al.* 2004; Devereux *et al.* 2015; Sebates-Wheeler *et al.* 2015). Two recent reviews highlight that mistargeting is a pervasive challenge across social programs regardless of the methodology (Devereux *et al.* 2017; White 2017). A range of community-level factors, including the level of socioeconomic development (Park *et al.* 2002), literacy (Baird *et al.* 2009) and broader political economy considerations (Sen 2002; Coady e*t al.* 2004; Baird *et al.* 2009; Premand and Schnitzer 2018) are shown to correlate with targeting performance. Yet, most empirical evidence in the literature that examines targeting methods in social programs focuses on methods that identify beneficiaries at the individual-level, with very limited evidence from programs using community-level targeting mechanisms. Community-level targeting methods (e.g., geographic targeting) may be appealing to policymakers that consider designing large-scale health programs to address regional inequalities, such as the imbalances in the distribution of the health workforce. In particular, community-level targeting methods may be preferable in settings where weak administrative capacity or lack of up-to-date information on community health needs hinder the implementation of large-scale programs (Schady 2002).

Similar to many low- and middle income countries, Brazil faces considerable challenges in access to healthcare services (Andrade *et al.* 2018b). Started in 1994, the Family Health Strategy (FHS) has become the bedrock of Brazil's Unified Health System (UHS) that guarantees universal healthcare access free-of-charge at point of use (Macinko and Harris 2015). As a community-based primary care delivery model, the FHS relies on multi-professional teams comprised of physicians, nurses and community health workers that serve up to 1,000 households residing in non-overlapping catchment areas (Andrade *et al.* 2018a). FHS teams typically provide a broad scope of preventive services and clinical assistance, including maternal and child health services, screening for avoidable cancers, monitoring the management of communicable and chronic conditions, and community outreach activities (Macinko and Harris 2015). All Brazilians are eligible to utilize FHS services free-of-charge. The expansion of the FHS led to improvements in access to primary care (Andrade *et al.* 2015), substantial reductions in maternal and child mortality (Rocha and Soares 2010; Rasella *et al.* 2010; Brentani *et al.* 2016), in racial inequalities in mortality amenable to primary care (Hone *et al.* 2017), and in hospitalizations and deaths due to conditions sensitive to primary care (Macinko *et al.* 2010; Macinko *et al.* 2011; Macinko *et al.* 2012; da Silva and Powell-Jackson 2017; Cavalcante *et al.* 2018).

Over the last two decades, the FHS scaled-up rapidly, though with considerable differences in its geographic coverage (Andrade *et al.* 2018a). Geographic imbalances in the distribution of physicians have persistently been highlighted as one of the most difficult challenges hindering the expansion of the FHS (Scheffer *et al.* 2013; Andrade *et al.* 2018b; Massuda *et al.* 2018). Against this backdrop, the Ministry of Health (MOH) introduced a supply-side intervention called the More Doctors Program (MDP) in 2013. The MDP became the world's largest government-led health program that recruited foreign and domestic physicians to serve in traditionally underserved communities. The MOH used an explicitly defined set of criteria to designate vulnerability status using administrative data. The vulnerability status was subsequently used to inform decisions for the distribution of MDP physicians. Similar to many other health programs, comprehensive analyses of the criteria used in the MDP to designate underserved community status on the implementation of the program remains limited, even though a growing body of literature examines the impact of the MDP on Brazilian health system performance (Fontes *et al.* 2018; Mattos and Mazetto 2019).

Our main objective is to study the performance of beneficiary targeting in the MDP in the period between 2013-2017. We built a 4-year time-series of municipal-aggregated data from multiple publicly available sources. We first documented the process of development and implementation of the MDP's criteria used to assign vulnerability status to municipalities. Next, we assessed the targeting performance of the MDP using an analytical framework that grouped municipalities into three categories: (1) successful enrollment, (2) under-coverage, and (3) non-target enrollment. Quantifying the magnitude of under-coverage allowed us to assess the ability of the MDP to reach target communities in accordance with the objectives of the program. In addition, quantifying the prevalence of non-target communities allowed us to examine the extent to which program resources were allocated to municipalities with fewer health personnel needs. Next, we investigated municipal-level differences across these three municipality classifications across four dimensions based on findings from earlier studies focusing on the factors associated with implementation of community-based primary care programs in decentralized settings (Andrade *et al.* 2018b; Andrade *et al.* 2018a): (1) socioeconomic development, (2) health system supply and resources, (3) population characteristics and (4) political considerations. We concluded by discussing the lessons learned from the Brazilian experience and their implications for other countries that are considering strategies for designing and implementing large-scale health programs using criteria-based approaches to identify underserved communities.

2.2. Study setting

A team of technical experts from the Primary Care Department of the Secretariat of Health Assistance (DAB-SAS) of the MOH and the Secretariat of Labor Management and Health Education (SGTES), with background in epidemiology, public health and statistical analysis designed the initial set of criteria used to designate vulnerability status to municipalities between 2013 and 2017. The SGTES technicians worked closely with DAB-SAS technicians who had familiarity with municipal-level data sources available to develop the set of criteria. The set of MDP prioritization criteria developed by the technical team built on previous federal initiatives that used criteria-based approaches to designate vulnerability status to municipalities, such as the Brazil without Misery Program, created in 2011 to reduce poverty in target communities, and the Program of Valorization of Health Professionals in Primary Care, created by the MOH in 2011 with a similar objective of increasing physician availability in underserved areas.

All vulnerability criteria were published in federal ordinances issued by the MOH. As shown in Table 2.1, the MDP prioritization criteria were revised twice. In each revision, the technical team took into account the level of poverty, geographic location and population size of municipalities, but selected a different combination of indicators to measure these variables. Most indicators used to define vulnerability were based on municipal-level administrative data collected by multiple agencies in different points in time, though more granular data from the 2010 Population Census were also used to identify communities within each municipality, where a considerable proportion of the population was living in remote areas.

The first set of criteria was published in Federal Ordinance 1369/MS/MEC on July 8, 2013, though they were never implemented (Ministério da Saúde 2013a). According to the initial criteria, vulnerability designation was granted to only a subset of municipalities that were listed in the 2011 Federal Ordinance 1377/GM/MS, which used a similar criteria-based approach for identifying a list of priority municipalities for UHS that had difficulty attracting and retaining trained health professionals. Regardless of their vulnerability designation, municipalities could also request MDP physicians in order to allocate them within remote and rural communities. The first revision to the MDP prioritization was issued within 10 days (Federal Ordinance 1493/MS/MEC, July 18, 2013). It retained all components of the first Federal Ordinance, except that it allowed municipalities to request MDP physicians to serve within districts with high levels of poverty (identified as census tracks within municipalities with at least 40% of the population living in extreme poverty), regardless of their vulnerability designation (Ministério da Saúde 2013a). A second revision, issued on March 31, 2014, in Notice SGTES 22, no longer limited vulnerability status to the municipalities listed in the 2011 Federal Ordinance (Ministério da Saúde 2014). It incorporated the municipal human development index (MHDI) and a broader set of geographic indicators. It also indicated that larger size municipalities with populations greater than 100,000 inhabitants were permitted to enroll in the program in order to allocate MDP physicians within communities with high levels of poverty.

Starting from 2014, all federal ordinances supplemented the MDP prioritization criteria discussed in Table 2.1 with a list of priority municipalities that were either (i) encouraged to apply to the MDP if they had not already done, or (ii) were eligible to receive more MDP physicians even if they had already received program physicians. Once a municipality received the vulnerable designation, it retained this status even if it did not qualify with the subsequent iterations of the prioritization criteria.

Table 2.1 Description of MDP vulnerability criteria used by the MOH, in chronological order, 2013-2017

Criteria definition	**Year**	**Source**
Legislation: Federal Ordinance 1.369/MS/MEC [8 July 2013]		
• Areas defined by the Federal Ordinance 1.377/GM/MS; AND	2011	MOH
• Municipalities with 20% or more of the population living with less than R$ 70 (equivalent to $US16.85); OR	2010	BAHD
• G100 Municipalities; OR	2011	NFM
• Special Indigenous Health Districts as established by 1999 Law No 9836/99	1999	MOH
• Census tracks categorized as 4 and 5 within municipalities (category 4 - rural census cluster with urban extension within 1km of urban center; category 5 - secluded rural settlements)	2010	IBGE
Legislation: Federal Ordinance 1.493/MS/MEC [18 July 2013]		
• Areas defined by the Federal Ordinance 1.377/GM/MS; AND	2011	MOH
• Municipalities with 20% or more of the population living with less than R$ 70; OR	2010	BAHD
• G100 municipalities; OR	2011	NFM
• Special Indigenous Health Districts as established by 1999 Law No 9836/99	1999	MOH
• Census tracks with at least 40% of the population living in extreme poverty	2010	IBGE
Legislation: Notice SGTES 22 [31 March 2014]		
• Municipalities with 20% or more of the population living with less than R$ 70; OR	2010	BAHD
• G100 municipalities; OR	2011	NFM
• Municipalities with Human Development Index among the ranges of very low or low; OR	2010	BAHD
• Municipalities in the following geographic areas: Jequitinhonha Valley in the State of Minas Gerais, Mucuri Valley in the State of São Paulo, Ribeira Valley in the States of São Paulo and Paraná, or semiarid regions in the Northeastern Region; OR		IBGE
• Municipalities with Quilombo settlements; OR		Palmares Cultural Foundation
• Municipalities with populations living in rural settlements with agrarian reform projects in the implementation phase according to the November 2013 Report of the Board of Land Procurement and Settlement Projects of the Ministry of Agrarian Development; OR	2013	Ministry of Agrarian Development
• Municipalities in the North or Northeast regions that do not fit in any other criteria		IBGE
• Census tracks with at least 40% of the population living in extreme poverty within large municipalities with a population of over 100,000 inhabitants	2010	2010 Population Census (IBGE)

The MOH organized the MDP enrollment process by periodically issuing public calls that invited municipalities to join the program. To enroll in the program, municipalities were required to submit an application to the MOH online portal, specify the number of physician vacancies that were required by the FHS teams in their communities, and indicate the specific FHS teams that the MDP physicians were planned to join. Any municipality, regardless of eligibility or current availability of physicians in the community, was able to submit an application. Upon receiving applications, project coordinators within the MOH analyzed the compliance of each application with the targeting criteria to validate or reject it. For validated applications, the MOH separately determined the number of physicians that would be allocated to each municipality using a different set of criteria. The criteria used to calculate the number of MDP physicians that would be sent to the municipalities were also published through Federal Ordinances. It was possible for non-vulnerable municipalities to contest their vulnerability designation by filing an appeal with the SGTES that demonstrated the needs of the local FHS teams through up-to-date information on local health provider availability in the community.

2.3. Methods

2.3.1. Study design

We started our analysis by mapping the MDP vulnerability status of each municipality for the period 2013-2017. To track MDP vulnerability status, we constructed a binary variable: a municipality was coded vulnerable, if it fitted at least one of the vulnerability criteria listed in Table 2.1 in a given year or if the municipality was included in the list of priority areas published in the public calls in a given year even if it did not fit any of the vulnerability criteria; otherwise, it was coded non-vulnerable. To construct this variable, we conducted a desk review of the MDP legislation that set the list of criteria used to determine the vulnerability status of municipalities. We corroborated our interpretation of the language used in the legislation through interviews with a small set of stakeholders who were involved in the development and implementation of the prioritization criteria. In these interviews, we asked interviewees to describe each criterion used for prioritization as outlined in the Federal Ordinances, and how each iteration of the prioritization criteria was implemented in practice (e.g. whether a community that qualified according to one Federal Ordinance as a vulnerable municipality retained its status in a subsequent iteration). We, then, compared municipal-level characteristics of these municipalities against those without vulnerability designation to ascertain whether the set of criteria used by the MOH was able to group municipalities into two distinct categories in line with the objectives of the MDP.

Next, we evaluated targeting performance over time. We adopted a commonly used analytical framework by Cornia and Stewart (1993) in the beneficiary targeting literature, as shown in Table 2.2. The framework considers two dimensions: enrollment status and vulnerability designation. To track enrollment, we constructed a binary variable for MDP enrollment defined as whether there was at least one MDP physician in the municipality at the end of each year (Appendix provides a detailed analysis of MDP enrollment). We, first, analyzed the rate at which target communities were successfully enrolled in the MDP and considered enrollment to be successful when vulnerable municipalities received MDP physicians (P_i/N_v) in a given year.

We then considered two conceptually different versions of mistargeting: under-coverage, and leakage. Under-coverage occurs when intended beneficiaries do not enroll in the program, whereas leakage occurs when program resources are allocated to unintended groups. Both types of mistargeting warrant a careful study – under-coverage may indicate the extent to which the program successfully reaches its target population, while leakage may signal inappropriate allocation of limited program resources (White 2017). In the case of MDP, the concept of leakage as often referred to in the literature may not be applicable, because all municipalities were eligible to receive MDP physicians regardless of their vulnerability designation. Therefore, we considered leakage municipalities as non-target enrollees if they received MDP physicians even though they were not designated as a priority.

We assigned municipalities under-coverage designation if they did not receive any MDP physicians despite meeting at least one of the vulnerability criteria. We calculated under-coverage as the percentage of vulnerable municipalities that did not receive any MDP physicians (P_e/N_v). We calculated non-target enrollment as the proportion of municipalities that received MDP physicians despite not meeting the MDP's vulnerability designation (NP_i/N_i).

Table 2.2 Classification of targeting performance used to measure targeting performance based on the enrollment and vulnerability dimensions

		Vulnerability status		
		Vulnerable municipality	Non-vulnerable municipality	Total
Enrollment status	Municipalities enrolled in MDP	P_i (successful enrollment)	NP_i (non-target enrollment)	N_i
	Municipalities unenrolled in MDP	P_e (under-coverage)	NP_e (non-enrollment)	N_e
	Total	N_v	N_{nv}	N

Notes: Municipalities that adhered to at least one of the vulnerability criteria defined by MOH in a given year or municipalities that were included in the list of priority municipalities published in federal ordinances between 2014-2017 were designated vulnerability status according to the MDP. MDP enrollment was defined as municipality having at least one MDP physician serving in the community. P_i refers to vulnerable municipalities that enrolled in MDP. NP_i and P_e present municipalities classified as special cases and under-coverage, respectively. N_v and N_v denotes the number of vulnerable and non-vulnerable municipalities. N denotes the overall sample size.

2.3.2. Sample and data sources

Our study sample included all 5,570 Brazilian municipalities in the period from 2013 to 2017. We tracked MDP enrollment status using aggregated administrative data obtained from the MOH. We obtained the list of priority municipalities for the UHS defined by the Federal Ordinance 1377/GM/MS from the MOH. We accessed the 2010 MHDI values from the Brazil Atlas of Human Development (BAHD), and categorized municipalities as: (i) very-low development - MHDI < 0.49, and (ii) low development – 0.5 < MHDI ≤0.59 (Atlas of Human Development in Brazil 2010). We obtained the list of G-100 municipalities from the National Front of Mayors (NFM) website. This group of municipalities was defined as those with more than 80,000 inhabitants, with the lowest levels of tax payment to the Brazilian National Treasury Department, and the highest level of social vulnerability (FNDP 2012). We extracted the list of municipalities that were included in the 34 Special Indigenous Health Districts from the MOH. We coded a binary variable that takes value one if the proportion of the population living in extreme poverty was 20% or more (and zero otherwise) using 2010 data from the Secretariat for Evaluation and Information Management website. Extreme poverty was defined as household income per capita under R$70 per month in 2010 (equivalent to $US16.85). We obtained data on the geographic location of municipalities from the Brazilian Institute of Geography and Statistics (IBGE), Ministry of Agrarian Development, and Palmares Cultural Foundation.

Recent studies on the implementation of community-based primary care programs in Brazil showed that the uptake and expansion of these programs can be examined across four dimensions(Andrade *et al.* 2018b; Andrade *et al.* 2018a): (1) level of socioeconomic development, (2) level of health care supply and resources, (3) population characteristics, and (4) political considerations.

To capture the level of socioeconomic development in each municipality, we used three proxy variables. First, we obtained the municipal gross domestic product (GDP) per capita between 2013 and 2017. Second, we extracted data from the Brazil Atlas of Human Development for the year 2010 to track the proportion of literate population aged 18 or older, defined as those who can read or write simple notes; and the proportion of population living in poverty, defined as household income per capita under R$140 per month (equivalent to $US33.70).

We measured health system supply using hospital beds per 1,000 inhabitants (except psychiatric beds) as a proxy. To capture physician supply in primary cares settings, we calculated (1) number of physicians per 1,000 inhabitants working at the primary care level, and (2) whether the municipality had a physician working in primary care in May 2013. We obtained these data from the MOH website for the years 2013-2017 (Ministério da Saúde 2019). In Brazil, the private sector plays an important role in both the financing and delivery of health care services. To account for the role of the private sector, we measured the proportion of the population with private insurance plans in each municipality for the years 2013 to 2017 using data from the Brazilian Regulatory Agency (Agéncia Nacional de Saúde Suplementar 2019).

We captured population characteristics using two variables: (1) population density and (2) population size. We include population characteristics in our analysis because the FHS coverage varies substantially across municipalities depending on their population density and size (Andrade *et al.* 2018). We calculated population density as the number of inhabitants by the area of the municipality measured in km^2. Data on the municipality area and population were obtained from the IBGE (IBGE 2019b). We coded population size as a categorical variable, as was done in Andrade *et al.* (2018b): <5000 inhabitants, 5000–9999 inhabitants, 10,000–19,999 inhabitants, 20,000–49,999 inhabitants and 50,000 or more inhabitants.

We considered political factors that may influence the implementation of large-scale primary care programs targeting underserved communities in highly decentralized settings. In Brazil, the health system is marked by a highly devolved governance structure, where municipalities enjoy a high degree of autonomy over decisions in financing and delivery of health services. Previous works from other settings showed that political alignment between government officials across levels of government has implications for the adoption and implementation of social policies (Sen 1992; Larcinese *et al.* 2006; Rodden 2006). More recently, Niedzwiecki (2016) demonstrated that the level of alignment between political parties of local and federal government officials can influence the implementation of social policies such as FHS and *Bolsa Família*, the world's largest conditional cash transfer program (Niedzwiecki 2016). Similarly, Andrade and colleagues showed in 2018 that the political party alignments of mayors and governors with the President was among the factors that influenced the uptake and implementation of FHS between 1994 and 2012 (Andrade *et al.* 2018b). Building on these findings, we adopted the approach used by Niedzwiecki (2016) to measure the level of political alignment between the President and mayors. We used political party labels in Presidential and mayoral elections using data from the Supreme Electoral Court website between 2012 and 2016 (Tribunal Superior Eleitoral 2019). We built a categorical variable to track political party alignment between mayors and the President in a given year. We coded this variable to take value zero if mayor was opposed to the president, one if the mayor and president were from the same party, and two if mayor and president were from the same political alliance in a given municipality.

2.3.3. Statistical analysis

We generated all maps with R-studio using *maptools* package. To assess the performance of community targeting, we assigned each municipality one of the three categories: successful targeting, and under-coverage and non-target. We tested the differences in the MDP physician density, level of socioeconomic development, health care supply and resources, population characteristics, and political considerations by performing a multivariate test of means, assuming heterogeneous covariance across the enrollment and vulnerability dimension. All calculations were done in Stata V16 (Stata Corp., College Station, TX, USA).

2.4. Results

Figure 2.1 displays vulnerability status by criteria. In 2013, about 24.4% of municipalities (1,361/5,570) were designated vulnerability status. Vulnerable municipalities were located across all geographic regions, though 76.9% (1,046/1361) were located in the Northeast, followed by 16.5% (224/1361) in the North. The revision of the vulnerability criteria in 2014 led to a marked expansion in the number of municipalities that were considered vulnerable, with approximately 60.4% (3,362/5,570) of all municipalities fitting at least one of the criteria. Of the municipalities that achieved vulnerability status in the 2014 revision, 37.4% (748/2,001) and 22.4% (448/2,001) were located in the Northeast and Southeast regions, respectively, and only 13% (261/2,001) in the Center-West. The number of municipalities with vulnerability status increased slightly after 2014, with approximately 66.9% (3,725/5,570) of municipalities in 2017 having vulnerability municipality designation (Appendix provides more details on the geographic distribution of vulnerable municipalities).

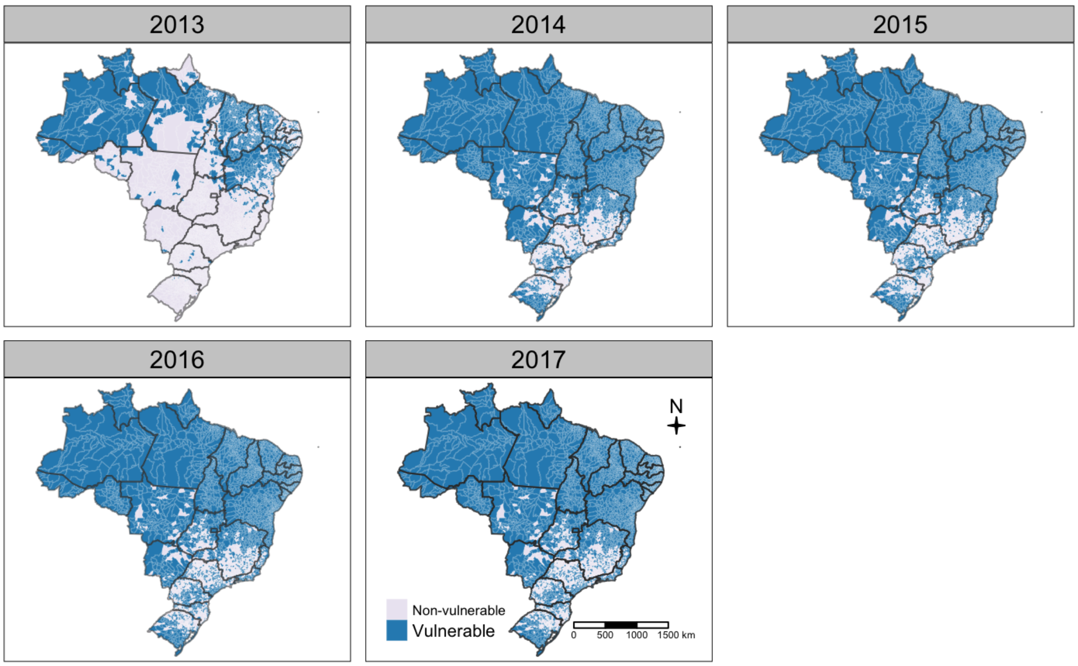

Figure 2. 1 Brazilian municipalities by MDP vulnerability status, 2013 to 2017

Notes: Light and dark blue denotes municipalities non-vulnerable and vulnerable designations in the MDP, respectively. State boundaries (federal units) are indicated in black.

We summarize selected municipal characteristics by vulnerability status in Table 2.3 and plot their distribution in Figure 2.2**.** Means tests for differences for select municipal indicators were all statistically significant, except physician availability at primary care settings and population density. Poverty rate among vulnerable municipalities was 17%, more than four times that of the poverty rate in non-vulnerable municipalities. Vulnerable municipalities had fewer hospital beds and physicians working in primary care before the launch of the MDP (1.22 hospital beds and 0.16 physicians per 1,000 inhabitants working in primary care), compared to non-vulnerable municipalities (1.37 hospital beds and 0.28 primary care physicians per 1,000 inhabitants). Around 23% of vulnerable and non-vulnerable municipalities lacked a primary care physician deployed in the community in May 2013, though this difference was not statistically different from zero. Population density was slightly higher among vulnerable municipalities, with 118 inhabitants per km^2, compared to 113 in non-vulnerable municipalities. But this difference was also not statistically significant. Almost 65% of municipalities with vulnerability designation had populations greater than 10,000 inhabitants, compared to about 45% among non-vulnerable municipalities. In terms of political party alignments, almost 92% of municipalities with vulnerability designation had mayors whose political parties were either the same or in political alliance with the President's party, compared to about 83% among non-vulnerable municipalities.

Table 2.3 Selected characteristics of municipalities by vulnerability status, 2013-2017

Characteristic	**Vulnerable**		**Non-vulnerable**		**Means test**	
	Mean,%	**SD**	**Mean,%**	**SD**	**F test**	**p-value**
GDP per capita (R$)	22798.71	31591.88	32696.94	35394.53	590.00	$p < 0.001$
Poverty rate (2010, %)	17.31%	12.28	3.74%	4.39	16353.18	$p < 0.001$
Literacy rate (2010, %)	77.58%	10.8	88.96%	6.25	12129.18	$p < 0.001$
Hospital beds per 1000 inhabitants	1.22	1.29	1.37	1.85	54.13	$p < 0.001$
Has physician working in primary care (2013, %)	22.9%	0.42	23.30%	0.42	0.37	0.55
Physician density per 1000 inhabitants working in primary care (2013)	0.16	0.18	0.28	0.34	1160	$p < 0.001$
Proportion of the population with private plans	5.17	0.09	11.51	0.12	2398.02	$p < 0.001$
Population density (inhabitants/km^2)	117.81	619.35	113.33	592.17	0.38	0.54
Population size						
<5000	14.66%		31.87%			
5000-9999	20.43%		23.59%		1240.42	$p < 0.001$
10000-19999	28.02%		20.26%			
20000-49999	23.12%		15.15%			
≥50000	13.77%		9.13%			
Political alliances						
Opposition	8.71%		17.27%			
Same party	7.11%		7.65%		438.66	$p < 0.001$
Alliance	84.18%		75.09%			

Notes: Municipalities that adhered to at least one of the vulnerability criteria defined by MOH in a given year or municipalities that were included in the list of priority municipalities published in federal ordinances between 2014-2017 were designated vulnerability status according to MDP. Analysis pools data from all Brazilian municipalities regardless of their MDP enrollment status. Multivariate tests of means were performed, assuming heterogeneous covariance between vulnerable and non-vulnerable municipalities. All data were pooled for the years 2013-2017, except poverty and literacy rates for the year 2010. SD = Standard deviation

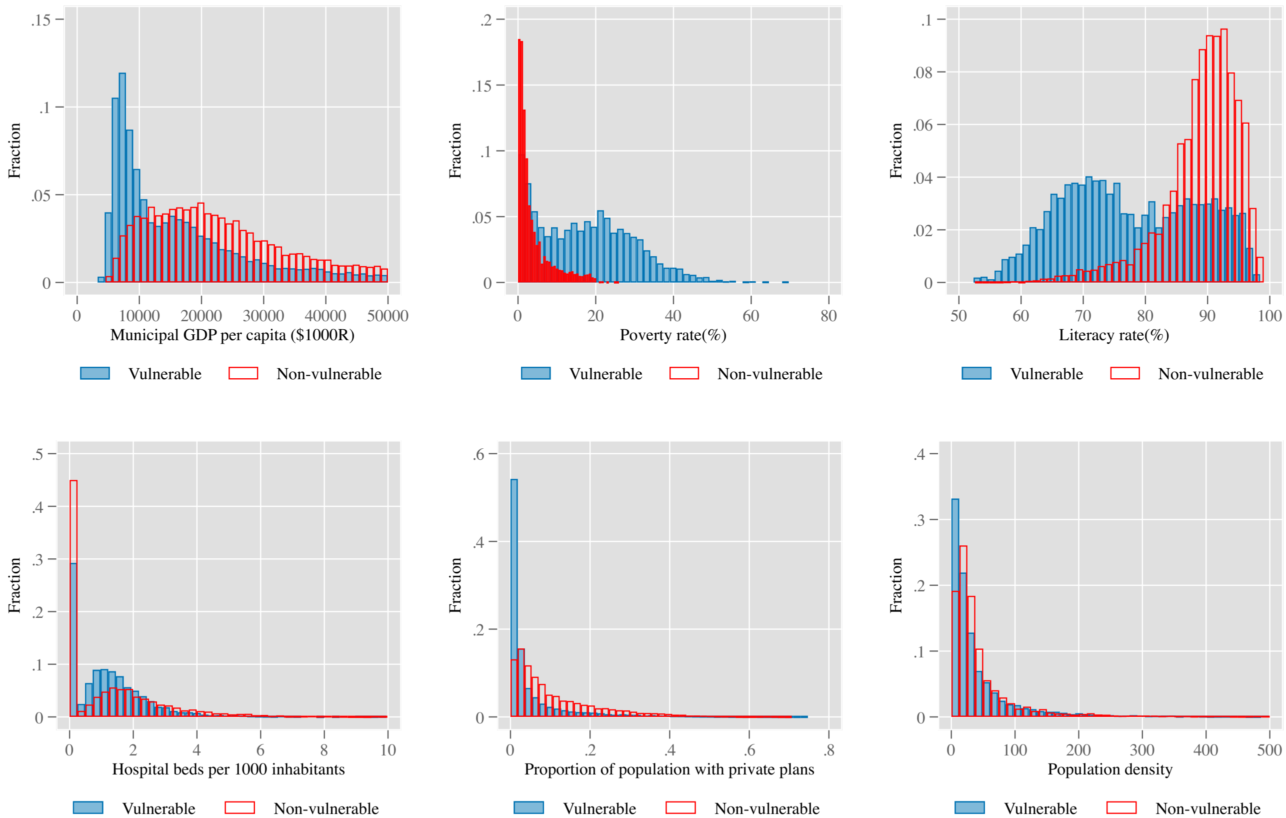

Figure 2. 2 Distribution of select municipality characteristics by MDP vulnerability status, 2013 to 2017

Notes: Vulnerability was defined as municipalities that adhered to at least one of the prioritization criteria defined by MOH in a given year. Data for all indicators were pooled for the years 2013-2017, except poverty and literacy rates, which are for the year 2010.

Figure 2.3 displays the geographic distribution of municipalities that were classified under one of the three outcomes describing targeting performance of the MDP. Considering successful targeting, we find that almost 70% of municipalities that enrolled in MDP between 2013 and 2017 fit at least one of the criteria to designate socioeconomically vulnerable community status. In the first year of the MDP implementation, successful enrollment among vulnerable municipalities was 45% (612/1,361). In the subsequent years, targeting accuracy improved substantially reaching 76.2% (2,840/3,725) in 2017. Non-target municipalities constituted a substantial share of MDP beneficiaries, with approximately 33% of municipalities that were enrolled in the program not fitting any of the vulnerability criteria between 2013 and 2017. In 2013, non-target municipalities represented 44.6% (492/1,104) of MDP beneficiaries. This share declined steadily in subsequent years to 25.6% (974/3814) in 2017 (Appendix provides more detailed information on the geographic distribution of municipalities by all three MDP target categories).

In Table 2.4, we show that primary care physician density per 1000 inhabitants was lowest among successful enrollment municipalities in May 2013, followed by under-coverage and non-target municipalities (0.16, 0.18 and 0.26 per 1000 inhabitants, respectively). Despite these disparities in the physician density working in primary care settings prior to the launch of the Program, the MDP physicians were similarly distributed between vulnerable municipalities that received MDP physicians and non-target municipalities (0.18 and 0.19 per 1,000 inhabitants, respectively). Next, we show that the greatest differences in terms of socioeconomic development and health system characteristics were between municipalities classified as under-coverage and non-target enrollment. For instance, the poverty rate among under-coverage municipalities was around 18%, almost six times that of the poverty rate in non-target enrollees. Under-coverage municipalities had fewer hospital beds and primary care physicians. In 2013, these municipalities had 1.12 hospital beds and

0.18 primary care physicians per 1,000 inhabitants, compared to 1.44 hospital beds and 0.26 primary care physicians in non-target municipalities, respectively. About 30% of under-coverage municipalities lacked a primary care physician, whereas one fifth of non-target enrollees did not have a primary care physician deployed prior to the implementation of MDP.

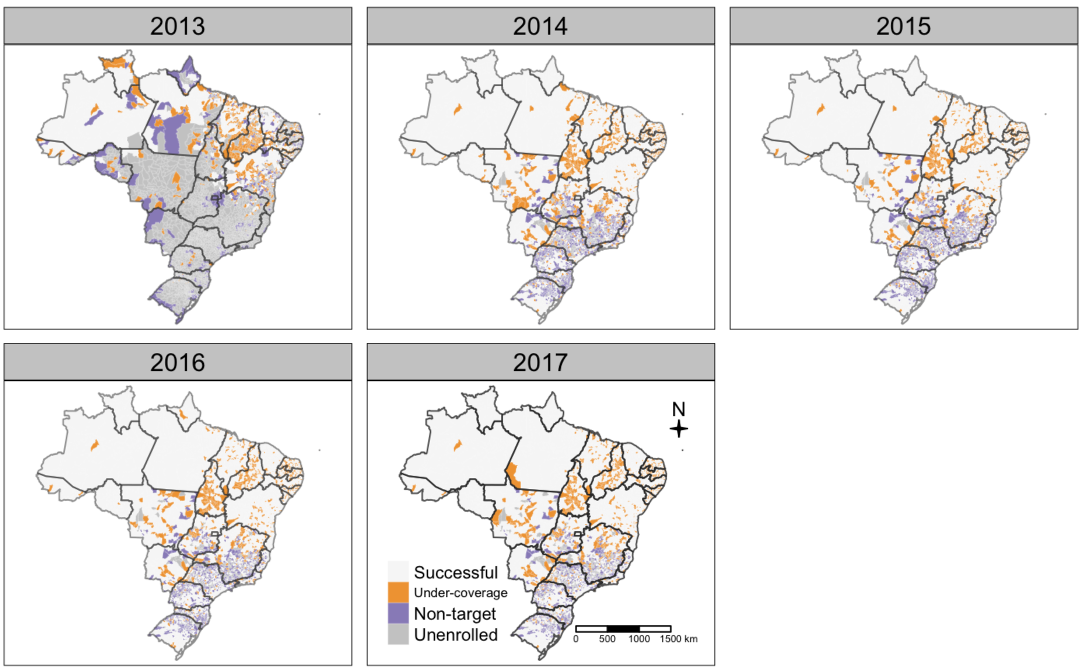

Figure 2. 3 Brazilian municipalities by MDP vulnerability and enrollment status, 2013 to 2017

Notes: White, orange and purple denote successful enrollment, under-coverage and non-target enrollment, respectively. State boundaries (federal units) are indicated in black.

Table 2.4 Selected characteristics of municipalities by enrollment and vulnerability domains, 2013-2017

Characteristic	Successful enrollment		Under-coverage		Non-target enrollment		Means test
	Mean,%	SD	Mean,%	SD	Mean,%	SD	p-value
GDP per capita (R$)	23306.7	35965.19	21379.29	36728.64	35183.37	34412.45	$p < 0.001$
Poverty rate (2010, %)	16.93%	4.67	18.38%	11.84	3.23%	3.89	$p < 0.001$
Literacy rate (2010, %)	78.52%	6.65	74.95%	10.29	90.07%	5.44	$p < 0.001$
Hospital beds per 1000 inhabitants	1.26	1.87	1.12	1.43	1.44	1.82	$p < 0.001$
Has physician working in primary care (2013, %)	20.43%	0.40	30.12%	0.46	20.71%	0.41	$p < 0.001$
Physician density per 1000 inhabitants working in primary care (2013)	0.16	0.17	0.18	0.18	0.26	0.30	$p < 0.001$
Proportion of the population with private plans	5.61	0.12	3.91	0.08	12.55	0.12	$p < 0.001$
Population density (inhabitants/km^2)	141.91	418.02	50.45	195.78	174.48	772.17	$p < 0.001$
Population size							
<5000	10.00%		27.66%		25.51%		
5000-9999	17.61%		28.32%		23.60%		
10000-19999	28.34%		27.12%		20.75%		$p < 0.001$
20000-49999	26.81%		12.83%		17.23%		
≥50000	17.24%		4.07%		12.92%		
Political alliances							
Opposition	8.14%		10.32%		12.46%		
Same party	7.75%		5.32%		7.97%		$p < 0.001$
Alliance	84.11%		84.37%		79.57%		
GDP per capita (R$)	11456		4100		5056		

Enrollment is considered successful when vulnerable municipalities receive MDP physicians. Under-coverage occurs when municipalities with vulnerability designation do not enroll in the MPD. Non-target municipalities are non-vulnerable municipalities that receive MDP physicians. Municipalities that adhered to at least one of the vulnerability criteria defined by MOH in a given year or municipalities that were included in the list of priority municipalities published in federal ordinances between 2014-2017 are designated vulnerability status according to MDP. Multivariate tests of means were performed, assuming heterogeneous covariance across municipalities classified as successful enrollment, under-coverage, non-target enrollment. All data are pooled for the years 2013-2017, except poverty and literacy rates for the year 2010. SD = Standard deviation

Under-coverage and non-target municipalities also differed in population size and density. About 56% of under-coverage municipalities had fewer than 10,000 inhabitants, compared to about 49% among non-target municipalities. Under-coverage municipalities were also more sparsely populated, with population density averaging at around 51 inhabitants per km^2, compared to 174 inhabitants per km^2 in non-target enrollees. In terms of political alignment, about 10% of under-coverage municipalities had mayors from parties in opposition to the political party of the President, compared to about 8% of vulnerable municipalities that received MDP physicians and 12% among non-target enrollees.

2.5. Discussion

While many studies on beneficiary targeting focus on individuals, we know relatively little about the consequences of community-level targeting methods in large-scale health programs. Evaluating the performance of community-targeting methods can help assess the extent to which the social program is able to reach its target populations and ascertain how program resources are distributed across communities. To address this gap in the literature, we studied the performance of community targeting in a large-scale primary care initiative from Brazil, called the More Doctors Program.

We showed that the set of criteria used by the MOH was able to group municipalities into two distinct categories by their level of socioeconomic development, health supply factors and population characteristics. Municipalities with vulnerability designation had the highest poverty rates and lowest levels of literacy. Compared to non-vulnerable municipalities, they also had lower supply of hospital beds and availability of primary care physicians. However, the MDP vulnerability criteria did not distinguish between vulnerable and non-vulnerable municipalities with no primary care physicians prior to the launch of the MDP.

We found that almost 70% of municipalities with vulnerability designation enrolled in MDP between 2013 and 2017. In this period, approximately one-third of municipalities that enrolled in the program were considered non-target municipalities. Targeting performance improved over time. MDP physician density in non-target municipalities was similar to vulnerable municipalities that successfully received MDP physicians, even though the density of physicians working in primary care prior to the implementation of the Program was the lowest among the latter group and under-coverage municipalities. This finding suggests that the MDP may have faced challenges in the distribution of MDP physicians between communities in accordance with its objective of addressing health worker shortages in Brazil's most underserved communities.

We observed stark differences between vulnerable municipalities that did not receive any MDP physicians and municipalities that received MDP physicians despite not meeting any of the vulnerability criteria. Non-target enrollees with higher levels of socioeconomic development, health infrastructure and physician availability were more likely to receive MDP physicians. Conversely, under-coverage municipalities had the highest poverty rate and the lowest supply of hospital beds and primary care physicians prior to the launch of the MDP. These municipalities were also sparsely populated and smaller in size. The political parties of the mayors in under-coverage municipalities were less aligned with the party of the President, compared to the vulnerable municipalities that received MDP physicians.

Our results provide three important lessons to policymakers that seek to understand challenges and strategies for designing and implementing large-scale health programs that use community-level targeting methods. First, our results highlight that criteria-based approaches to identify underserved communities is a complex process that requires careful consideration of various design choices. We show that the MDP vulnerability definitions were able to discriminate communities that had lower levels of socioeconomic development, and lower health supplies and resources as vulnerable. However, the vulnerability criteria did not allow the identification of municipalities that did not have any primary care physicians at baseline, even though addressing physician shortages was the primary objective of the program. In their review, Devereux *et al.* (2017) highlight that policymakers that consider beneficiary targeting may benefit from carefully considering the consequences of the design choices on the implementation of social programs. Similarly, our findings suggest that in large-scale programs that aim to address health system challenges in vulnerable areas, the choice of indicators to designate vulnerability status should be informed by careful consideration of the underlying causes of vulnerability in the unique to the context.

Second, our results indicate that the choice of beneficiary targeting method is a prominent feature of large-scale health programs that present various trade-offs for policymakers. For instance, Wheeler *et al.* (2015) highlight that community-level targeting methods such as geographic targeting may be preferable because of their ease of administration and relatively low costs. However, these methods are also shown at the expense of targeting accuracy (Sabates-Wheeler *et al.* 2015). In Brazil, the MOH used readily available data to construct MDP vulnerability designations. However, our findings suggested that the MDP faced considerable challenges in beneficiary targeting in the study period. While targeting performance improved over time; non-target municipalities remained a substantial proportion of MDP beneficiaries, whereas one-third of target municipalities opted out of the program. Our findings corroborate findings from two recent reviews (Sabates-Wheeler *et al.* 2015; Devereux *et al.* 2017).

Third, our results indicate that the targeting performance is influenced not only by the design choices made by policymakers but also by the implementation process. We find marked differences between under-coverage and non-target municipalities, with under-coverage municipalities having substantially lower GDP per capita and population density. Our results suggest that policymakers may benefit from taking into account the unique barriers facing communities with low socioeconomic development and population density while designing and implementing large-scale health programs. Our results are in line with findings from Andrade *et al.* (2018), which demonstrated that both low population density and population size represented a significant challenge in the expansion of the FHS.

This study presents the first comprehensive assessment of beneficiary targeting in Brazil's More Doctors Program between 2013-2017 by utilizing data from multiple, municipal-level publicly available sources. It adopts a conceptual framework commonly used in the beneficiary targeting literature that allows for a systematic assessment of targeting performance over time. Our approach extends the literature on beneficiary targeting by providing new evidence from a large-scale health program that relied on a community-level targeting method to identify target communities. The results highlight the complexities associated with the design and implementation of a community-based targeting mechanism to address the inequitable distribution of health personnel.

This study has some limitations. First, an important design feature of the MDP was that municipalities were required to submit online applications to the MOH to join the program. Upon receiving applications, the MOH would evaluate whether the municipality fit vulnerability designation to inform decisions related to MDP physician allocations. In principle, the MOH could deny the application of municipalities to receive MDP physicians. In our study, we did not have information on the number of denied applications. It is plausible that a portion of municipalities we considered as non-enrolled municipalities were those whose applications were denied by the MOH. However, we do not expect this to be a considerable limitation, as earlier works indicated that denial of municipal applications was rare (Oliveira *et al.* (2016). Second, we were unable to determine whether, among municipalities considered non-target, the MDP physicians were actually placed within communities with a high proportion of the population living in extreme poverty, because data on MDP implementation is at the municipality level. It is plausible that some of the non-target municipalities allocated the MDP physicians within the FHS teams that work with highly vulnerable populations with greater health needs than the populations living within targeted municipalities. Alternatively, it is possible that the MDP physicians recruited to the non-target municipalities worked in non-vulnerable communities because the MOH did not monitor in which census tracts MDP physicians worked once they were placed in a municipality. Future studies with more granular data can examine MDP's targeting accuracy within non-target municipalities. Third, we were unable to measure the proportion of municipalities that had to contest their vulnerability status due to lack of data. However, our results showed that a considerable proportion of program beneficiaries were considered non-target municipalities, suggesting that some portion of these municipalities had to contest their status by providing more up-to-date information on their health resource needs to the MOH. This process of contestation of vulnerability status may have created an administrative burden. Fourth, our choice of municipal-level indicators was limited by publicly available and reliable data. For instance, we did not have information on the strength of physician associations in each municipality or local community groups, even though they might have been relevant to influencing decisions of local politicians related to the community's enrollment in MDP. Fourth, we were unable to identify the main factors that contributed to the improvements in beneficiary targeting. Future studies are needed to understand why targeting performance improved over time. In our analysis, we considered municipalities as enrolled in the MDP if they received at least one physician from the program, because we aimed to assess how beneficiary targeting at the community level changed over time. While our approach enabled us to track the number of municipalities that received MDP physicians over time, we were unable to provide an in-depth assessment of the changes in the number of physicians within and across municipalities in accordance the priorities of the MDP. Future studies can examine the different set of municipal-level criteria used by the MOH to determine the number of MDP physicians allocated to each municipality and assess whether changes in the number of MDP physicians reflect prioritization of communities set by these criteria.

2.6. Conclusion

This study investigated the performance of beneficiary targeting in a large-scale health program in Brazil using data from multiple municipal-level, publicly available sources. In 2019, the Brazilian Government replaced the MDP with a new large-scale health program called the *Médicos pelo Brasil* (MPS). Similar to the More Doctors Program, the MPS aims to address physician gaps in underserved municipalities. The MPS identifies target municipalities using a new set of targeting rules including the urbanization level of the municipality, population size, population density, and distance of municipality from large urban centers (Brazil 2019). Lessons from this study will pave the way for a follow-up analysis to assess the extent to which challenges faced in the implementation of the More Doctors Program were addressed by the MPS.

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Appendix

Figure A2.1 displays the distribution of MDP physicians across geographic regions between 2013 and 2017. Our results show that the MDP expanded most rapidly in the first year of implementation (2013-2014), with the number of enrolled municipalities increasing from 1,104 in 2013 to 3,725 in 2014 and 3,987 in 2015. Following this rapid expansion, the number of MDP municipalities started to decline to 3,882 in 2016 and to 3,814 in 2017. Among the MDP municipalities that enrolled in 2013, the drop-out rate remained relatively low in subsequent years, standing at 2.89% (33/1104) in 2014 and 4.08% (45/1104) in 2017. Of 2,654 municipalities that joined the MDP in 2014, the program drop-out increased from about 2.52% (67/2654) in 2015 to 8.25% (219/2654) in 2017. Among municipalities that joined the MDP after 2014, only 2.16% (32/1481) discontinued the program by 2017. The MDP enrollees were located across all geographic regions between 2013 and 2017, though the geographic distribution of MDP enrollees shifted over time.

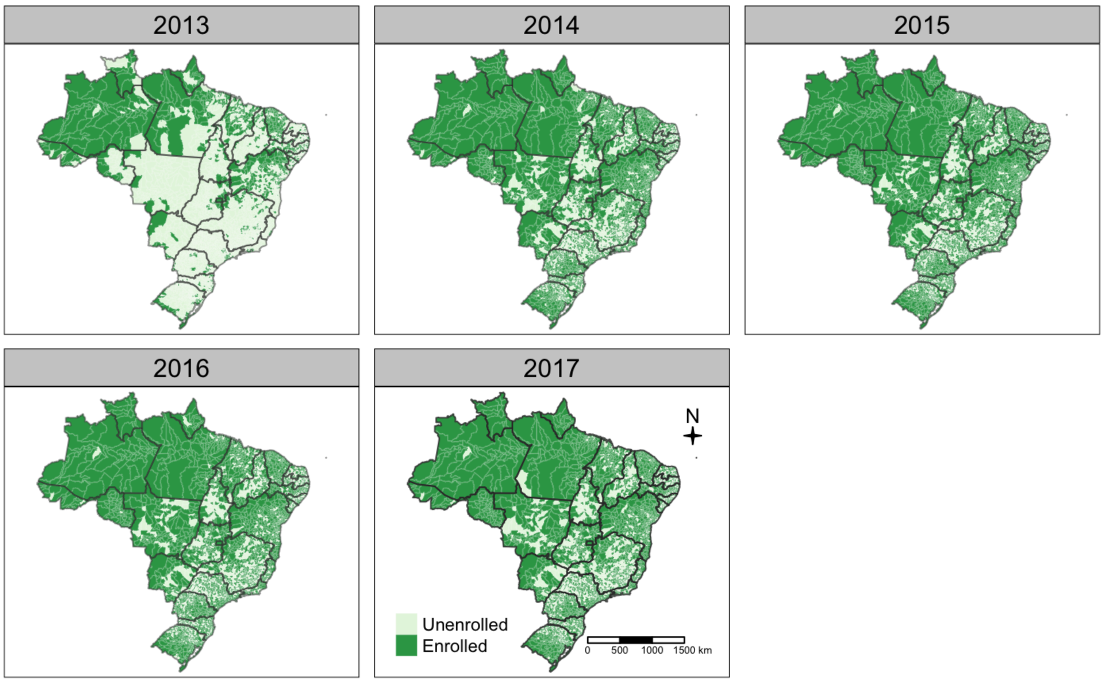

Figure A2. 1 Brazilian municipalities by MDP enrollment status, 2013 to 2017

Notes: Light and dark green denotes municipalities unenrolled and enrolled in the MDP, respectively. State boundaries (federal units) are indicated in black.

Table A2. 1 MDP enrollment and vulnerability designation by geographic region, 2003-2017

Panel A. MDP enrollment	2013		2014		2015		2016		2017	
	%	N	%	N	%	N	%	N	%	N
Center-West (N=467)	4.08	45	7.81	291	8.23	328	8.22	319	8.13	310
North (N=450)	17.21	190	9.61	358	9.23	368	9.27	360	9.62	367
Northeast (N=1794)	54.62	603	34.74	1294	34.69	1383	34.11	1324	34.66	1322
South (N=1191)	10.78	119	23.33	869	22.57	900	22.64	879	22.63	863
Southeast (N=1668)	13.32	147	24.51	913	25.28	1008	25.76	1000	24.96	952
Total (N=5570)		*1104*		*3725*		*3987*		*3882*		*3814*
Panel B. MDP vulnerability designation	2013		2014		2015		2016		2017	
	%	N	%	N	%	%	N	%	N	%
Center-West (N=467)	1.54	21	8.39	282	8.35	290	8.40	305	8.40	313
North (N=450)	16.46	224	13.38	450	12.95	450	12.39	450	12.08	450
Northeast (N=1794)	76.86	1046	53.36	1794	51.63	1794	49.38	1794	48.16	1794
South (N=1191)	1.32	18	9.99	336	10.68	371	12.03	437	12.94	482
Southeast (N=1668)	3.82	52	14.87	500	16.40	570	17.81	647	18.42	686
Total (N=5570)		*1361*		*3362*		*3475*		*3633*		*3725*

Notes: Municipalities with at least one MDP physician were considered enrolled in the program. Municipalities that adhered to at least one of the vulnerability criteria defined by MOH in a given year or municipalities that were included in the list of priority municipalities published in federal ordinances between 2014-2017 were designated vulnerability status according to MDP. N column denotes the overall sample size. % column refers to the percentage of total municipalities enrolled in the MDP and designated vulnerability status in a given year.

Table A2.2 summarizes selected municipality characteristics by year of enrollment in the MDP. Means tests for differences for select municipal indicators are all statistically different from zero, except political party alignments. Our results show that the poverty rate was 19.75% among municipalities enrolled in the MDP 2013, more than double that of the poverty rate among municipalities that enrolled in the MDP in subsequent years. In terms of health system characteristics, the 2013 enrollees had the lowest supply of beds and physicians working in primary care settings, with 1.07 beds and 0.15 physicians per 1,000 inhabitants, respectively. The proportion of the population with private insurance plans was also the lowest. We also find that almost 85% of 2013 enrollees had a population size greater than 10,000 inhabitants and population density averaged at about 317.84 inhabitants per km^2. However, this composition shifted after 2013 to favor smaller size municipalities and communities with lower population density. For instance, municipalities populations greater than 10,000 inhabitants represented about 56% of enrollees in 2014 and 64% of municipalities that enrolled in 2015 and after. The population density was 65.33 and 92 inhabitants per km^2 among 2014 enrollees and municipalities enrolled after 2014, respectively. About 89% of mayors of 2013 enrollees were either from the same political party or alliance as the President. The composition of political alignments among MDP enrollees changed slightly over time, but the differences in political party alignments between municipalities that enrolled in 2013 and subsequent years were not statistically significant.

Table A2. 2 Selected characteristics of municipalities by MDP enrollment year, 2013-2017

Characteristic	2013 enrollees (N=1104)		2014 enrollees (N=2654)		2015+ enrollees (N=368)		Means test	
	Mean, %	**SD**	**Mean, %**	**SD**	**Mean, %**	**SD**	**Wald Chi2**	**p-value**
GDP per capita (R$)	19102	22602.11	28620	32817.04	27163.88	26636.98	542.29	$p < 0.001$
Poverty rate (2010, %)	19.75%	13.2	9.61%	10.47	8.93%	9.72	2713.86	$p < 0.001$
Literacy rate (2010, %)	77.74%	11.65	83.97%	9.88	83.22%	10.84	1224.41	$p < 0.001$
Hospital beds per 1000 inhabitants	1.07	0.89	1.42	1.59	1.5	2.03	393.45	$p < 0.001$
Has physician working in primary care (2013, %)	15.94%	0.37	23.89%	0.43	17.66%	0.38	179.09	$p < 0.001$
Physician density per 1000 inhabitants working in primary care (2013)	0.15	0.16	0.21	0.25	0.21	0.21	370.12	$p < 0.001$
Proportion of the population with private plans	6.03	0.11	8.11	0.1	9.31	0.12	140.20	$p < 0.001$
Population density (inhabitants/km^2)	317.84	1102.01	65.33	419.37	91.48	256.2	276.24	$p < 0.001$
Population size								
<5000	4.58%		21.37%		12.88%%			
5000-9999	10.58%		24.49%		22.72%			
10000-19999	23.79%		27.29%		23.21%		2910.92	$p < 0.001$
20000-49999	33.59%		17.62%		27.61%			
≥50000	27.46%		9.22%		13.59%			
Political alliances								
Opposition	10.56%		11.90%		12.17%		1.64	0.44
Same party	10.09%		7.97%		5.33%			
Alliance	79%		80.14%		82.50%			

Table A2. 3 Performance of targeting (N=5570) – successful targeting, under-coverage and non-target enrollment, 2003-2017

	2013		2014		2015		2016		2017	
Panel A. Successful enrollment	%	N	%	N	%	N	%	N	%	N
Center-West	1.47	9	8.17	203	8.26	225	8.41	235	8.27	235
North	24.18	148	14.40	358	13.51	368	12.88	360	12.92	367
Northeast	69.61	426	52.05	1294	50.77	1383	47.39	1234	46.55	1322
South	0.33	2	11.58	288	12.00	327	13.71	383	14.44	410
Southeast	4.41	27	13.80	343	15.46	421	17.61	492	17.82	506
Total (N=1361, 3362, 3475, 3633, 3725)	44.97	612	73.94	2486	78.39	2724	76.91	2794	76.24	2840
Panel B. Under-coverage	2013		2014		2015		2016		2017	
	%	N	%	N	%	N	%	N	%	N
Center-West	1.60	12	9.02	79	8.66	65	8.34	70	8.81	78
North	10.15	76	10.50	92	10.92	82	10.73	90	9.38	83
Northeast	82.78	620	57.08	500	54.73	411	56.02	470	53.33	472
South	2.14	16	5.48	48	5.86	44	6.44	54	8.14	72
Southeast	3.34	25	17.92	157	19.84	149	18.47	155	20.34	180
Total (N=1361,3362,3475,3633,3725)	55.03	749	26.06	876	21.61	751	23.09	839	23.76	885
Panel C. Non-target enrollment	2013		2014		2015		2016		2017	2
	%	N	%	N	%	N	%	N	%	N
Center-West	7.32	36	7.10	88	8.16	103	7.72	84	7.70	75
North	8.54	42	-	-	-	-	-	-	-	-
Northeast	35.98	177	-	-	-	-	-	-	-	-
South	23.78	117	46.89	581	45.37	573	45.59	496	46.51	453
Southeast	24.39	120	46.00	570	46.48	587	46.69	508	45.79	446
Total(N=1104,3725,3987,3882,3814)	44.57	492	33.26	1239	31.68	1263	28.03	1088	25.54	974

Notes: Enrollment is considered successful when vulnerable municipalities received MDP physicians. Under-coverage occurs when municipalities with vulnerability designation did not enroll in the MPD. Non-target municipalities are non-vulnerable municipalities that received MDP physicians. Municipalities that adhered to at least one of the vulnerability criteria defined by MOH in a given year or municipalities that were included in the list of priority municipalities published in federal ordinances between 2014-2017 were designated vulnerability status according to MDP. N column denotes the overall sample size. % column refers to the percentage of total municipalities that were grouped into successful enrollment, under-coverage and non-target enrollment categories.

Chapter III

Impact of Brazil's More Doctors Program on avoidable hospitalizations for cardiovascular conditions

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Abstract

Introduction: Globally, cardiovascular diseases are the leading cause of disease burden and death. Timely and appropriate provision of primary care may lead to sizeable reductions in hospitalizations for a range of chronic and acute health conditions, referred to as avoidable hospitalizations. In this paper, we study the impact of Brazil's More Doctors Program (MDP), once the world's largest government-led foreign physician recruitment initiative, on avoidable hospitalizations for cardiovascular conditions.

Data and Methods: We exploit the geographic variation in the uptake of the MPD to perform a quasi-experimental study that incorporates coarsened exact matching and difference-in-difference methods. We use data from the Hospital Information System in Unified Health System, the MDP administrative records, the Brazilian Regulatory Agency, the Ministry of Health, and the Brazilian Institute of Geography and Statistics, covering the period between 2009 and 2017.

Results: We show that the MDP led to 10.04 (95%CI: -19.16, -0.92) fewer hospitalizations per 100,000 municipal inhabitants for avoidable cardiovascular conditions, with the effects of the program increasing over time. In addition, observed reductions in hospitalizations were primarily from rural municipalities, 17.15 (95%CI: -30.74,-3.57) fewer hospitalizations per 100,000 inhabitants for avoidable cardiovascular conditions. Stratifying the analysis by specific conditions resulted in estimated MDP coefficients of -1.41 (95%CI: -3.98,1.16) for cerebrovascular disease, -3.51 (95%CI: -8.91,1.89) for heart failure and -0.94 (95%CI: -5.23, 3.35) for hypertension, but none of them reached statistical significance.

Conclusions: Our results highlight that increased investment in resources devoted to primary care led to improvements in hospitalizations for avoidable cardiovascular conditions.

3.1. Introduction

Globally, cardiovascular diseases are the leading cause of disease burden and death (Naghavi *et al.* 2017). The worldwide number of deaths attributable to cardiovascular diseases is estimated to have increased from approximately 11.9 to 17.1 million deaths between 1990 and 2015 (IHME 2018). Low- and middle-income countries bear a considerable share of the disease burden, with more than 80% of global deaths due to cardiovascular diseases now occurring in these settings (Murray *et al.* 2012; Yusuf *et al.* 2014; Naghavi *et al.* 2017). In response to the rising burden of non-communicable diseases, the World Health Organization's Global Action Plan for the Prevention and Control of Non-Communicable Diseases (NCDs) set a target of 25% relative reduction in premature mortality from cardiovascular diseases, cancer, diabetes and chronic respiratory diseases by 2025 (WHO 2013).

The Global Conference on Primary Health Care in 2018 renewed global commitment to strengthening primary care provision. Primary care has been proposed as a cost-effective strategy to address the rising NCD burden by improving prevention, early detection, treatment and long-term management of chronic disease (WHO 2013; WHO 2018a; WHO 2018b). Previous studies demonstrate a positive relationship between primary care strengthening and better health outcomes, as well as improvements in the quality and efficiency of health care delivery and patient satisfaction (Shi *et al.* 2002; Macinko *et al.* 2003; Starfield *et al.* 2005; Macinko *et al.* 2009; Kringos *et al.* 2010; Kruk et al. 2010; Shi 2012; Starfield 2012; Kringos *et al.* 2013; Doubova *et al.* 2016; Macinko 2019). However, most empirical evidence comes from high-income settings, with few causal study designs (Friedberg *et al.* 2010; Kringos *et al.* 2010; Glied and Smith 2011).

An extensive literature shows that timely and appropriate provision of primary care may lead to sizeable reductions in hospitalizations for a range of chronic and acute health conditions, referred to as avoidable hospitalizations (Billings *et al.* 1993; Ansari 2007). Previous studies indicate that high rates of avoidable hospitalizations may signal challenges in access to and quality of primary care, inadequate distribution of resources for health, or a mismatch between the availability of services and the needs of the population (AHRQ 2001; Laditka *et al.* 2003; Caminal *et al.* 2004; Ansari 2007; Rosano *et al.* 2012). Yet, available evidence on the relationship between increased investment in primary care and avoidable hospitalizations is mixed and most evidence is generated through ecological studies (Rosano *et al.* 2012; Gibson *et al.* 2013). Several studies found that there was an inverse relationship (Laditka *et al.* 2005; Rizza *et al.* 2007; Arrieta and Garcia-Prado 2015), whereas others showed a positive or no association between access to primary care and avoidable hospitalizations (Schreiber and Zielinski 1997; Ricketts *et al.* 2001). Moreover, most empirical evidence comes from high-income settings, including the United States, Canada, Australia, and European health systems (Weissman *et al.* 1992; Cloutier-Fisher *et al.* 2006; Purdy *et al.* 2009; Magán *et al.* 2011; Rosano *et al.* 2012).

In this study, we address the gap in the literature by assessing the impact of Brazil's More Doctors Program (MDP) on avoidable hospitalizations for cardiovascular conditions. We further examine the impact of the MDP between urban and rural municipalities where previous works documented disparities (Schmidt *et al.* 2011). Brazil's main platform for primary care provision, known as the Family Health Strategy (FHS), plays an integral role in the country's strategy for the prevention of NCDs (Macinko *et al.* 2010; Schmidt *et al.* 2011). Since its launch in 1994, the FHS has become the world's largest community-based primary care program, reaching more than 122 million people (Macinko and Harris 2015; Andrade *et al.* 2018a). Over the last two decades, the FHS was scaled up rapidly. However, there were considerable disparities in the proportion of the population covered across geographic regions (Massuda *et al.* 2018). Imbalances in the distribution of physicians, rather than a shortage, has been highlighted as one of the most difficult challenges undermining efforts for equitable expansion of the FHS (Andrade *et al.* 2018a).

Established in 2013 and discontinued in 2019, MDP was the world's largest government-led physician recruitment initiative to strengthen primary care provision in traditionally underserved communities (Ministério da Saúde 2019). The MDP entailed the recruitment of a cadre of domestic and foreign physicians to serve in municipalities where previous attempts to attract Brazilian physicians proved difficult. A unique feature of the program was that MDP physicians were required to work exclusively in primary care settings, where they would either fill physician gaps in existing FHS teams or contribute to the formation of new teams. This feature was put in place to ensure program implementation was aligned with the objective of strengthening primary care provision, and it provides a valuable opportunity to study the relationship between primary care physician availability and avoidable hospitalizations.

We identified the effect of the MDP by exploiting the geographic variation in the uptake of the program to design a quasi-experimental study that incorporates coarsened exact matching and difference-in-difference methods, using data from several publicly available data sets, covering the period between 2009 and 2017. As our main primary outcomes, we selected avoidable cardiovascular diseases, cerebrovascular disease, heart failure, hypertension, and others. Together, these conditions are the leading cause of death and hospitalizations in Brazil. We estimated hospitalizations per 100,000 inhabitants as a function of enrollment in the MDP, time-varying municipality-level controls, and area and time fixed effects. To the best of our knowledge, this study provides the first causal evidence of the impact of the MDP on avoidable hospitalizations for cardiovascular conditions.

The remainder of the paper is organized as follows: Section 3.2 presents the More Doctors Program. Section 3.3 describes the data sources and methods. Section 3.4 presents the main estimates of the effects of the MDP on avoidable hospitalizations and results from several sensitivity checks. Section 3.5 discusses the implications of our findings for Brazil and their significance for other health systems as well as areas for further research. Section 3.6 concludes.

3.2. More Doctors Program

In Brazil, NCDs—specifically, cardiovascular diseases—represent the leading cause of death. In 2015, NCDs accounted for approximately 74% of all deaths, with cardiovascular diseases representing about one-third of these deaths (Victora *et al.* 2011; IHME 2018). The burden of cardiovascular deaths is more pronounced in poorer regions of the country (Schmidt *et al.* 2011). In response to this challenge, Brazil launched a series of national health initiatives, including the Strategic Action Plan for Management of Chronic Non-Communicable Diseases in 2011 that promoted a range of interventions, including smoking secession, physical activity and healthy diets, and reducing the harmful use of alcohol (Duncan *et al.* 2012).

The FHS is the main platform for primary care provision, and services are delivered by multi-professional FHS teams comprised of physicians, nurses and community health workers, that serve up to 1,000 households residing in non-overlapping catchment areas. During their monthly visits, the FHS teams screen patients for major risk factors related to cardiovascular diseases in accordance with the national guidelines and protocols. Based on these patient assessments, the FHS teams then make recommendations, including smoking cessation, changes in dietary habits and increasing physical activity. For high-risk patients, the FHS teams can prescribe medication. They also track whether patients are taking their medications as prescribed and assess whether prescription refills are needed. All Brazilians are eligible to utilize FHS services free of charge. Earlier studies demonstrate that the expansion of FHS led to improvements in health system performance (Macinko *et al.* 2007; Elias *et al.* 2008; Aquino *et al.* 2009; Bastos *et al.* 2017; Hone *et al.* 2017; Nery *et al.* 2014; Rasella *et al.* 2010) with substantial reductions in hospitalizations for conditions sensitive to primary care (Macinko *et al.* 2010; Macinko *et al.* 2011; Cavalcante *et al.* 2018) and deaths due to cerebrovascular and cardiovascular diseases among adults (Rasella *et al.* 2014).

With the aim of reducing imbalances in the distribution of physicians working in FHS teams, the MDP was launched in 2013 by the Ministry of Health (MOH). The MOH was the main government agency responsible for overseeing the implementation of the MDP; it recruited foreign physicians, developed strategies to determine the allocation of physicians to participating municipalities in accordance with their needs, and paid the wages of MDP physicians. The municipal governments were mainly responsible for covering the cost of lodging and food expenses. Service contracts were renewed every three years. Unlike other physicians working in FHS, it was required that the MDP physicians had prior experience in family medicine. Upon acceptance into the program, they enrolled in a mandatory three-week course, which covered topics including the service delivery in Brazil's National Health System and Portuguese language classes. MDP physicians were also required to attend regular, brief training courses organized by Brazilian health authorities at regular intervals, and they could enroll in online medical education classes. MDP physicians were supervised by Brazilian health professionals who provided guidance on their medical inquiries. The

MDP physicians were not obligated to pass the placement tests typically required before foreign physicians may practice medicine in Brazil. Once placed in local communities, MDP physicians were required to practice medicine only within the organization of the FHS. The MDP physicians were either integrated into existing FHS teams or contributed to the formation of new teams.

The geographic coverage of the MDP expanded rapidly, with the proportion of municipalities that enrolled in the program increasing from almost 20% (1104/5570) in 2013 to about 68% (3814 /5570) in 2017. To distribute MDP physicians across communities, the MOH ranked municipalities by priority based on a set of criteria including the proportion of the population living in poverty, geographic location and population size (A more detailed description of the geographic expansion of the MDP and prioritization criteria used by the MOH is discussed in Chapter 2).

3.3. Methods

Our main unit of analysis in the post-CEM sample is 5,564 out of Brazil's 5570 municipalities in the period between 2009-2017. We merged patient hospital discharge data, MDP administrative records, and time-varying municipal-level controls using unique municipality codes obtained from the Brazilian Institute of Geography and Statistics (IBGE). We present an overview of the variables (and their data sources) used in this study in Table A3.1 in the Appendix.

We obtained de-identified administrative data on the number of MDP physicians working in municipalities between 2013-2017 from the MOH. We measured socioeconomic development using the municipal gross domestic product (GDP) per capita (in log scale) for the years 2009-2017 using data from the IBGE. We used administrative records from the MOH to construct an indicator of the number of hospital beds per 1,000 inhabitants, excluding psychiatric beds. For data available on a monthly basis, we used July as a temporal reference, as was done in previous studies (Andrade *et al.* 2018b, Andrade *et al.* 2018a). Using data from the Brazilian Regulatory Agency, we controlled for the proportion of the population with private health plans to account for the public-private provider mix in each municipality. We also included a control for the proportion of the adult population 20 years of age and older in the municipality provided by the IBGE. We built a categorical variable to capture the size of the municipal population using data from the IBGE. Population size was coded in five categories: <5,000 inhabitants, 5,000–9,999 inhabitants, 10,000–19,999 inhabitants, 20,000–49,999 inhabitants, and 50,000 or more inhabitants. Finally, we obtained the list of municipalities with populations living in rural settlements (Damasceno *et al.* 2017) based on classifications developed in November 2013 by the Board for Land Acquisition and Settlements Implementation in the Ministry of Agrarian Development. Similar to IBGE, we classified municipalities with no rural settlements as urban areas (IBGE 2017).

Our primary outcome is the number of avoidable hospitalizations by municipality of residence for cardiovascular conditions sensitive to primary care per 100,000 inhabitants. We scaled our outcome variables by population size because the distribution of the number of hospitalizations was skewed. These conditions included cerebrovascular disease, heart failure, hypertension, and other cardiovascular conditions including angina and acute myocardial infarctions. We selected these outcomes on the basis of the list of primary care sensitive conditions published by the MOH in 2008, as well as findings from earlier studies (Ministério da Saúde 2008; Macinko *et al.* 2009; Cavalcante *et al.* 2018; Dantas *et al.* 2018). To construct these outcomes, we merged data from two publicly available data sets. First, we obtained patient hospital discharge records from the Hospital Information System (HIS). The HIS is a national database of patient records that contains information for all hospitalizations financed by the national health system, including public hospitals, private and non-profit facilities. We extracted data using the International Classification of Diseases, Tenth Revision (ICD-10) groupings for the period 2009-2017 (All hospitalizations in the HIS after 1999 are recorded using ICD-10 groupings [Macinko *et al.* 2011]). We accessed data on the number of residents living in each municipality from publicly available population counts reported by the IBGE.

A central challenge in assessing the impact of the MDP on hospitalizations is the non-random roll-out of the program across municipalities. Difference-in-difference methods rely on the assumption that after controlling for municipal-level observable characteristics and trends, changes in our primary outcomes are independent of the enrollment status in the MDP. When this assumption fails, the difference-in-difference estimates are biased, because the method is unable to distinguish between changes in the outcomes that are attributable to the program and those that are not (Lindner and McConnell 2018). In our study, the main source of concern stems from the MDP enrollment process, whereby municipalities were required to submit an application to the MOH to enroll in MDP. If this application process was burdensome, it may have led some municipalities to opt not to submit an application to join the program.

A growing literature suggests the combination of the difference-in-difference method with coarsened exact matching (CEM) in order to reduce bias in causal inference where program roll-out is not random (Ho *et al.* 2007; Stuart 2010; Winship and Morgan 2014; Ryan *et al.* 2015; Lindner and McConnell 2018; Ryan *et al.* 2019). CEM enables a reduction in the imbalances in the observable characteristics between the treatment and control municipalities by temporarily pruning data, while simultaneously retaining a representative sample. In our study, CEM is appealing for several reasons.

First, CEM permits us to leverage the information we have on the criteria used by the MOH for the prioritization of municipalities to allocate MDP physicians for matching treatment and control municipalities (King and Nielsen 2016; Stuart *et al.* 2014). CEM reports the overall imbalance in the matched sample using the multivariate L_1 distance statistic, which measures the differences distribution of time-varying controls between treatment and control groups. Blackwell and colleagues (2009) suggest using the multivariate L_1 distance statistic for comparisons; reductions in L_1 distance before and after matching indicates a successful reduction in the overall imbalance of the data. Any remaining imbalance in the CEM-matched sample can be controlled for by including variables in the regression analysis (Blackwell *et al.* 2009). Other advantages of CEM are explained in detail elsewhere (Iacus *et al.* 2012; Blackwell *et al.* 2009; O'Neill *et al.* 2016; Chabé-Ferret 2015; King *et al.* 2011; King and Nielsen 2016; Stuart *et al.* 2014).

We performed CEM in the following steps. First, we defined treatment municipalities as those that received at least one MDP physician deployed in the community and the control municipalities were those that did not receive an MDP physician during the study period. Next, we temporarily coarsened municipality-level controls, including geographic region, population size, hospital beds per 1000 inhabitants and a binary indicator for whether the proportion of the population that lives in extreme poverty exceeded 20% of the population. We selected these controls for CEM, because the MOH used these indicators to allocate MDP physicians to municipalities and previous studies showed that these municipal-level factors were associated with the uptake and expansion of primary care programs in Brazil (Chapter 2; Andrade *et al.* 2018a; Andrade *et al.* 2018b). We also included the proportion of population 20 years and above (Macinko *et al.* 2011) to account for demographic characteristics in each municipality (Table A3.2 in the Appendix presents the specific cut off points selected coarsening). Next, we performed exact matching on the coarsened data. In this step, observations were sorted into a set of strata with unique cut-off points assigned for each control we used for the coarsening. Any stratum that did not have at least one treatment and one control municipality were pruned. We then used the uncoarsened observations, minus those pruned, in subsequent regressions. We used weights generated by CEM in the difference-in-difference analyses.

To evaluate the impact of MDP on hospitalizations, we exploited the geographic variation in program enrollment across municipalities for an intention-to-treat analysis. Using the MOH administrative records on the number of MDP physicians, we constructed $\boldsymbol{MDP_{mt}}$, the binary indicator that takes value one starting from the year of MDP enrollment for municipality *m* in time *t*, and zero otherwise. The value of the $\boldsymbol{MDP_{mt}}$ indicator remains one even if municipality *m* is unenrolled in the MDP in a subsequent year. We adopted this approach because it was plausible that the MDP had unintended effects on the medical practices of health workers in host communities. With time, the MDP physicians and health workers may have had more opportunities to interact with each other, which provided an opportunity for mutual learning. Alternatively, health behaviors among patients may have changed if they were exposed to health education and promotion activities (Ghisi *et al.* 2014). Given this unique feature of the program, the potential educational effects of the MDP may have endured even after MDP physicians left their posts. We estimated a linear model to examine the impact of the program, as shown in Equation 1:

$$\boldsymbol{Y_{mt} = \gamma MDP_{mt} + \delta X_{mt} + \varphi_m + \rho_{st} + \varepsilon_{mj}} \tag{1}$$

where $\boldsymbol{Y_{mt}}$ denotes the key hospitalization variables in municipality *m* in year *t*. $\boldsymbol{X_{mt}}$ is the vector of time-varying municipality controls that may be correlated with the outcome variables, including municipal GDP per capita, the number of hospital beds per 1,000 inhabitants, the proportion of the population with private health plans , the proportion of the population aged 20 years and above, and population size. $\boldsymbol{\varphi_m}$ represents municipality fixed effects unobserved time-invariant municipality characteristics (e.g., geography) to account for permanent differences between municipalities that may correlate with key hospitalization outcomes. The term $\boldsymbol{\rho_{st}}$ denotes a series of state-by-year fixed effects. We included state-by-year fixed effects because Brazilian states had considerable discretion in terms of health and non-health initiatives during the study period. Finally, the term $\boldsymbol{\varepsilon_{mj}}$ is the residual. The main parameter of interest in Equation 1 is the term $\boldsymbol{\gamma}$, which captures the average change in hospitalization outcomes between the treatment and control municipalities.

Equation 1 yields the average changes in hospitalization outcomes attributable to MDP. However, this approach masks information on the temporal dynamic nature of the program implementation. For instance, some of the effects of stronger primary care may not be immediately evident, as shown by previous studies (Cesur *et al.* 2017; Fontes *et al.* 2018). Moreover, we hypothesize that the effects of the MDP may not be immediately observable. For instance, once in the municipality, the local government needed to decide whether the MDP physician would fill gaps in existing FHS teams or contribute to the formation of new teams. New FHS teams had to become operational, which entailed allocating personnel to the new teams, identifying and registering new patients, and starting home-visits to designated patients. Moreover, it might also have taken time for the MDP physicians to learn the medical needs and disease profiles of their new patients and align their own medical practice with FHS clinical guidelines for the management of chronic diseases. Even though the MDP physicians were required to attend training courses while practicing medicine in Brazil, these learning opportunities may not have been sufficient to fully prepare them for their new work contexts right away. Finally, the presence of MDP may also have influenced the behaviors of citizens, because it may take time for physicians and patients to build relationships, a crucial factor in the continuity of care in primary care settings (Starfield 1998). To capture the temporal aspect of the program, we estimated a linear model as shown in Equation 2:

$$\boldsymbol{Y_{mt}} = \boldsymbol{\beta_0} + \boldsymbol{\beta_1 X_{mt}} + \boldsymbol{\beta_2}\mathbf{MDP}_{\boldsymbol{mt}}^{0} + \sum_{k=1}^{+4} \boldsymbol{\beta_k MDP_{mt}} + \boldsymbol{\varphi_m} + \boldsymbol{\rho_{st}} + \boldsymbol{\varepsilon_{mj}} \qquad (2)$$

Equation 2 includes a separate dummy variable for the year of MDP enrollment and subsequent year of program implementation. In this model, the impact of the MDP is represented by the estimated coefficient of $\mathbf{MDP}_{\boldsymbol{mt}}^{0}$, and the effects in subsequent years is captured by the estimated coefficients on $\boldsymbol{\beta_k MDP_{mt}}$. Our approach implies that the impact of the MDP in the year that the municipality enrolled in the program may differ from the effects of the MDP in subsequent years. In all models, we clustered standard errors at the municipality level to account for heteroskedasticity and serial correlation within municipalities across time. To examine whether the MDP affected avoidable hospitalizations differently across municipalities, we further stratified our analytical sample by location type (i.e. urban versus rural).

We performed several robustness checks. A key difference-in-difference assumption is that enrollment in the MDP is not correlated with pre-existing trends in key hospitalization outcomes after we control for the time-varying municipality controls, time-invariant area effects, state-time controls, and common trends. To test the plausibility of this assumption, we conducted an event study analysis. We replaced the treatment variable in Equation 1 with a continuous measure that tracks the number of years since MDP enrollment. Next, we performed joint F-tests to ascertain whether the estimated coefficients in the period prior to the MDP enrollment were statistically different from one another (Goodman-Bacon 2018). Additional robustness and falsification tests are detailed in the Appendix. We performed all statistical analyses using the Stata statistical package, version 15.1.

3.4. Results

Table **3.1** presents descriptive statistics on hospitalization outcomes and control variables. Columns 2 and 3 show that MDP and non-MDP municipalities vary substantially in the pre-matched sample. MDP municipalities had fewer hospitalizations for all outcomes, fewer hospital beds per 1,000 inhabitants, and smaller populations, compared to non-MDP municipalities. All control variables, except the proportion of the population with private health plans , were statistically different between MDP and non-MDP municipalities. Prior to CEM, the multivariate L_1 distance was 0.29, and the overall sample size was 50,130 observations. After we applied the CEM, only a small number of observations were pruned, and the study sample remained representative of the population with 50,076 observations. The multivariate L_1 distance reduced to 0.22, indicating that we successfully reduced bias in the overall distribution of the covariates, but some imbalance remained in the post-CEM sample between treatment and control groups. We also observed statistically significant differences in the empirical distribution of control variables for the municipal GDP per capita, hospital beds per 1,000 inhabitants and the proportion of the population above the age of 20. However, these differences were considerably smaller in the matched sample, as shown in Table **3.1** and displayed in Figure 3.1. We proceeded with the matched sample in the subsequent analyses and controlled for these variables in order to adjust for the remaining imbalances in the matched data (Blackwell *et al.* 2009).

Table 3.1 Descriptive statistics of Brazilian municipalities before and after coarsened exact matching, 2009-2017

		Before CEM			After CEM	
	Full sample	MDP	Non-MDP	p-values	Non-MDP	p-values
Panel A. Avoidable hospitalizations per 100 000 inhabitants						
All avoidable CVDs	457.88	419.01	478.44	$p < 0.001$	455.76	$p < 0.001$
	(326.32)	(306.05)	(334.73)		(323.70)	
Cerebrovascular diseases	107.43	106.10	108.13	0.01	103.17	$p < 0.001$
	(80.40)	(76.27)	(82.50)		(78.90)	
Heart failure	166.79	139.41	181.26	$p < 0.001$	171.57	$p < 0.001$
	(185.84)	(164.26)	(194.75)		(184.81)	
Hypertension	60.78	50.62	66.15	$p < 0.001$	67.72	$p < 0.001$
	(117.20)	(113.68)	(118.67)		(119.23)	
Panel B. Municipality characteristics						
Per capita municipal GDP (log scale)	9.44	9.59	9.35	$p < 0.001$	9.31	$p < 0.001$
	(0.74)	(0.69)	(0.75)		(0.76)	
Hospital beds per 1 000 inhabitants	1.35	1.31	1.37	$p < 0.001$	1.43	$p < 0.001$
	(1.60)	(1.46)	(1.67)		(1.52)	
Proportion of the population with private health insurance coverage	0.08	0.08	0.08	0.27	0.08	0.13
	(0.11)	(0.11)	(0.11)		(0.11)	
Proportion of adult population ≥ 20 years of age	0.66	0.67	0.66	$p < 0.001$	0.65	$p < 0.001$
	(0.06)	(0.06)	(0.06)		(0.07)	
Population size						
Less than 5 000 (%)	0.23	0.16	0.26	$p < 0.001$	0.16	0.02
	(0.42)	(0.36)	(0.44)		(0.37)	
5 000-9 999 (%)	0.22	0.20	0.23	$p < 0.001$	0.20	0.34
	(0.41)	(0.40)	(0.42)		(0.40)	
10 000-19 999 (%)	0.25	0.26	0.24	$p < 0.001$	0.26	0.13
	(0.43)	(0.44)	(0.43)		(0.44)	
20 000-49 999 (%)	0.19	0.23	0.17	$p < 0.001$	0.22	0.02
	(0.39)	(0.42)	(0.38)		(0.41)	
≥50 000 (%)	0.11	0.15	0.09	$p < 0.001$	0.14	0.03
	(0.32)	(0.36)	(0.29)		(0.35)	
Number of observations	50130	17341	32789		32735	
Multivariate L_1 distance				0.29		0.22

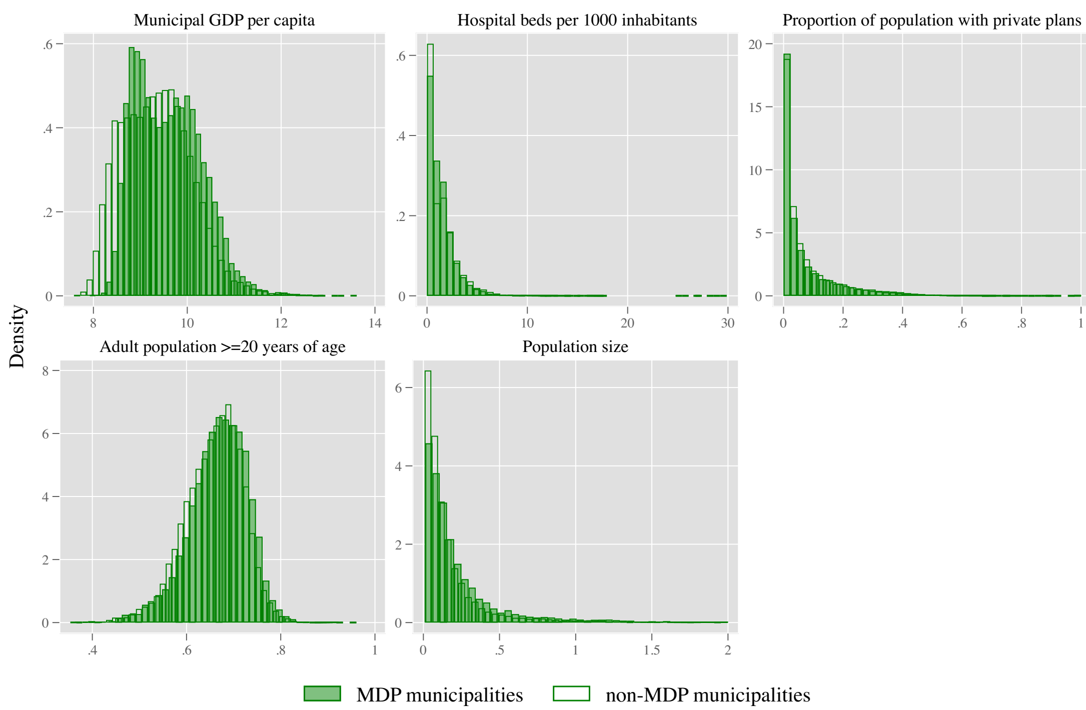

Figure 3.1 Distribution of select time-varying municipality characteristics in the matched sample, 2009-2017

Notes: Data were pooled for the period 2009-2017. Time-varying municipality characteristics included the log of GDP per capita, hospital beds per 1,000 inhabitants, proportion of the population with private insurance plans, proportion of adult population ≥ 20 years of age, and population size (expressed in millions). Municipalities with populations greater than 2 million people were dropped from density graphs for ease of display.

Table 3.2 presents the estimated impact of MDP on avoidable hospitalizations per 100,000 inhabitants. We show that there was an inverse relationship between the MDP and hospitalizations due to avoidable cardiovascular conditions we examined. We find that the estimated MDP coefficient for hospitalizations due to cardiovascular diseases was -10.04 (95%CI: -19.16, -0.92). This finding suggests that for an average sized municipality (with approximately 36,000 inhabitants), there were about 3.6 fewer avoidable cardiovascular hospitalizations attributable to the MDP compared to non-MDP municipalities. The estimated coefficients for MDP were -1.41 (95%CI: -3.98,1.16) for cerebrovascular disease, -3.51 (95%CI: -8.91,1.89) for heart failure and -0.94 (95%CI: -5.23, 3.35) for hypertension, but none of them reached statistical significance (Different model specifications for our principle regression are presented in the Appendix).

Table 3.2 Impact of the MDP on avoidable hospitalizations in the matched sample

	(1)	(2)	(3)	(4)
	All avoidable CVDs	CD	HF	HP
Controls for time-varying municipality controls, municipality fixed effects, state-by-year fixed effects				
MDP implementation	-10.04	-1.41	-3.51	-0.94
	[-19.16,-0.92]	[-3.98,1.16]	[-8.91,1.89]	[-5.23,3.35]
Constant	372.52	54.32	284.86	-10.64
	[104.05,640.98]	[-20.34,128.97]	[125.63,444.09]	[-137.41,116.13]
N	50076	50076	50076	50076
R^2	0.79	0.65	0.75	0.65

Notes: All regressions were performed with CEM weights. Outcome variables are hospitalizations per 100,000 inhabitants. Data on hospitalization outcomes was based on the patient discharge records by the place of residence from the Hospital Information System of the public hospitals. 95%CIs are in brackets. Time-varying municipality characteristics include the municipal GDP per capita (in log scale), hospital beds per 1,000 inhabitants, proportion of the population with private insurance plans, proportion of adult population ≥ 20 years of age, and population size. CVD: Cardiovascular diseases, CD = Cerebrovascular disease, HF = Heart failure, HY = Hypertension. All standard errors were clustered at the municipality-level.

Table 3.3 presents estimated results that capture the temporal nature of the relationship between the MDP and avoidable hospitalizations. In these models, we replaced the binary MDP treatment variable with a set of dummy variables that tracked the number of years since initial enrollment in the program. Results suggest that the estimated impact of the MDP on avoidable hospitalizations for cardiovascular diseases persisted and grew over time. For cardiovascular disease, the estimated MDP coefficient was -5.36 (95%CI: -13.46,2.75) in the year of program introduction, -15.46 (95%CI:-27.91,-3.01) in its second year and it stood at -25.73 (95%CI: -45.60,-5.87) in the fourth year. These results suggest for an averaged sized municipality, the MDP was associated with 5.6 fewer avoidable hospitalizations in its second year, with this number increasing to 9.2 fewer hospitalizations by the fourth year of implementation. We observed a similar pattern for cerebrovascular diseases, where the estimated coefficient on MDP became statistically different from zero starting from the third year, and the magnitude of the estimated coefficient increased in the next year. Once again, this finding suggests that it took time for the program effects to be observed. We find no evidence that the program led to any measurable decline in hospitalizations for heart failure and hypertension.

Table 3.3 Impact of the MDP on avoidable hospitalizations in the matched sample, dynamic estimation

	(1) All avoidable CVDs	(2) CD	(3) HF	(4) HP
MDP (Year 0)	-5.36	-0.46	-2.55	0.42
	[-13.46,2.75]	[-2.90,1.99]	[-7.21,2.12]	[-3.70,4.54]
MDP (*Year 1)*	-9.70	-0.35	-4.06	-2.15
	[-20.09,0.70]	[-3.37,2.66]	[-10.24,2.11]	[-7.17,2.88]
MDP (*Year 2)*	-15.46	-1.82	-5.18	-2.60
	[-27.91,-3.01]	[-5.41,1.76]	[-12.50,2.13]	[-8.85,3.65]
MDP (*Year 3)*	-17.88	-5.09	-3.70	-1.50
	[-32.84,-2.91]	[-9.28,-0.89]	[-12.21,4.81]	[-9.15,6.14]
MDP (*Year 4)*	-25.73	-8.05	-4.03	-0.52
	[-45.60,-5.87]	[-13.48,-2.62]	[-14.80,6.73]	[-11.06,10.02]
Constant	373.72	54.87	284.85	-10.78
	[105.57,641.86]	[-19.71,129.44]	[125.64,444.06]	[-137.47,115.91]
N	50076	50076	50076	50076
R^2	0.79	0.65	0.75	0.65

Notes: All regressions were performed with CEM weights. Outcome variables are hospitalizations per 100,000 inhabitants. Data on hospitalization outcomes was based on the patient discharge records by the place of residence from the Hospital Information System of the public hospitals. 95%CIs are in brackets. Time-varying municipality characteristics include the municipal GDP per capita (in log scale), hospital beds per 1,000 inhabitants, proportion of the population with private insurance plans, proportion of adult population ≥ 20 years of age, and population size. CVD: Cardiovascular diseases, CD = Cerebrovascular disease, HF = Heart failure, HY = Hypertension. All standard errors were clustered at the municipality-level.

Table 3.4 presents results by location type. Panel A shows the MDP average treatment effects and indicates that in rural municipalities the MDP was associated with 17.15 (95%CI: -30.74,-3.57) fewer hospitalizations per 100,000 inhabitants for cardiovascular diseases. However, none of the estimated MDP coefficients were statistically different from zero for urban municipalities. Panel B evaluates dynamic effects of the MDP on hospitalizations and shows that in rural municipalities the MDP led to measurable reductions in avoidable hospitalizations, with the estimated MDP coefficient becoming more negative over time from -9.56 (95%CI: -22.58,3.45) in the year of MDP introduction to -40.58 (95%CI: -72.03,-9.13) in the fourth year. The MDP coefficient became statistically significant in the first year following the program introduction, indicating that it took time for the program effects to become observable. In urban municipalities, the estimated MDP coefficient remained statistically insignificant for all hospitalization outcomes, except cerebrovascular diseases, where we observed discernable program effects in the fourth year.

Figure 3.2 plots the estimated coefficients from our event study analyses. For hospitalizations due to cardiovascular and cerebrovascular diseases, we observed declining trends prior to the introduction of the Program, though none of the estimated coefficients in the pre-MDP period were statistically different from zero. For heart failure, we noted statistically significant declines in hospitalizations in four and three years prior to the MDP implementation, but the estimated coefficient in two years prior to the MDP implementation was not statistically significant. For hypertension, none of the estimated coefficients in the pre-MDP period reached statistical significance. The joint F-tests further showed that there were no statistically detectable differences between the estimated coefficients in the pre-MDP period for our hospitalization outcomes, suggesting that observed declining trends in hospitalization rates were not statistically different from zero.

Table 3.4 Impact of the MDP on avoidable hospitalizations by type of residence

	Rural				Urban			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	All avoidable CVDs	CD	HF	HP	All avoidable CVDs	CD	HF	HP
Panel A								
MDP	-17.1	-1.6	-5.7	-7.4	-5.5	-1.3	-1.8	1.9
	[-30.7,-3.5]	[-5.6,2.4]	[-13.3,1.9]	[-15.0,0.3]	[-17.6,6.5]	[-4.7,2.0]	[-9.2,5.5]	[-3.2,7.1]
Constant	402.0	-0.0	359.3	-2.5	650.8	158.6	282.3	23.4
	[-55.3,859.4]	[-121.4,121.4]	[66.4,652.3]	[-291.9,287.0]	[424.7,877.0]	[88.8,228.5]	[161.6,403.1]	[-58.8,105.6]
N	18243	18243	18243	18243	31833	31833	31833	31833
R^2	0.79	0.67	0.75	0.67	0.79	0.63	0.75	0.64
Panel B.								
MDP (Year 0)	-9.6	-0.8	-4.5	-2.8	-2.1	0.1	-0.7	1.9
	[-22.6,3.5]	[-4.4,2.7]	[-11.1,2.1]	[-10.9,5.3]	[-12.4,8.1]	[-3.2,3.4]	[-7.0,5.5]	[-2.4,6.1]
MDP *(Year 1)*	-17.6	0.0	-5.8	-9.0	-3.7	-0.5	-2.0	1.4
	[-33.5,-1.8]	[-4.7,4.8]	[-14.8,3.1]	[-18.3,0.3]	[-17.3,9.8]	[-4.4,3.4]	[-10.3,6.3]	[-4.4,7.2]
MDP *(Year 2)*	-28.3	-2.5	-7.6	-14.1	-7.6	-1.5	-3.1	3.0
	[-48.0,-8.6]	[-8.4,3.3]	[-18.1,3.0]	[-26.4,-1.8]	[-23.7,8.5]	[-6.1,3.1]	[-12.9,6.8]	[-4.1,10.2]
MDP *(Year 3)*	-32.4	-5.6	-8.1	-14.7	-11.1	-5.0	-0.5	3.4
	[-56.7,-8.0]	[-12.3,1.0]	[-20.6,4.4]	[-30.8,1.4]	[-30.2,7.9]	[-10.5,0.4]	[-11.9,10.9]	[-4.7,11.5]
MDP *(Year 4)*	-40.6	-7.8	-9.4	-18.2	-20.7	-8.5	-0.4	6.6
	[-72.0,-9.1]	[-16.2,0.7]	[-25.3,6.5]	[-38.3,1.8]	[-46.5,5.1]	[-15.8,-1.2]	[-15.2,14.5]	[-4.6,17.8]
Constant	398.6	-0.8	358.8	-4.1	327.7	96.5	217.2	-27.2
	[-58.0,855.3]	[-122.0,120.5]	[66.1,651.5]	[-293.9,285.7]	[-37.0,692.4]	[-6.2,199.2]	[16.5,417.8]	[-155.8,101.4]
N	18243	18243	18243	18243	31833	31833	31833	31833
R^2	0.79	0.67	0.75	0.67	0.79	0.63	0.75	0.64

Notes: All regressions are performed with CEM weights. Outcome variables are hospitalizations per 100,000 inhabitants. Data on hospitalization outcomes is based on the patient discharge records by the place of residence from the Hospital Information System of the public hospitals. 95%CIs are in brackets. CVD: Cardiovascular diseases, CD = Cerebrovascular disease, HF = Heart failure, HY = Hypertension. All standard errors are clustered at the municipality-level.

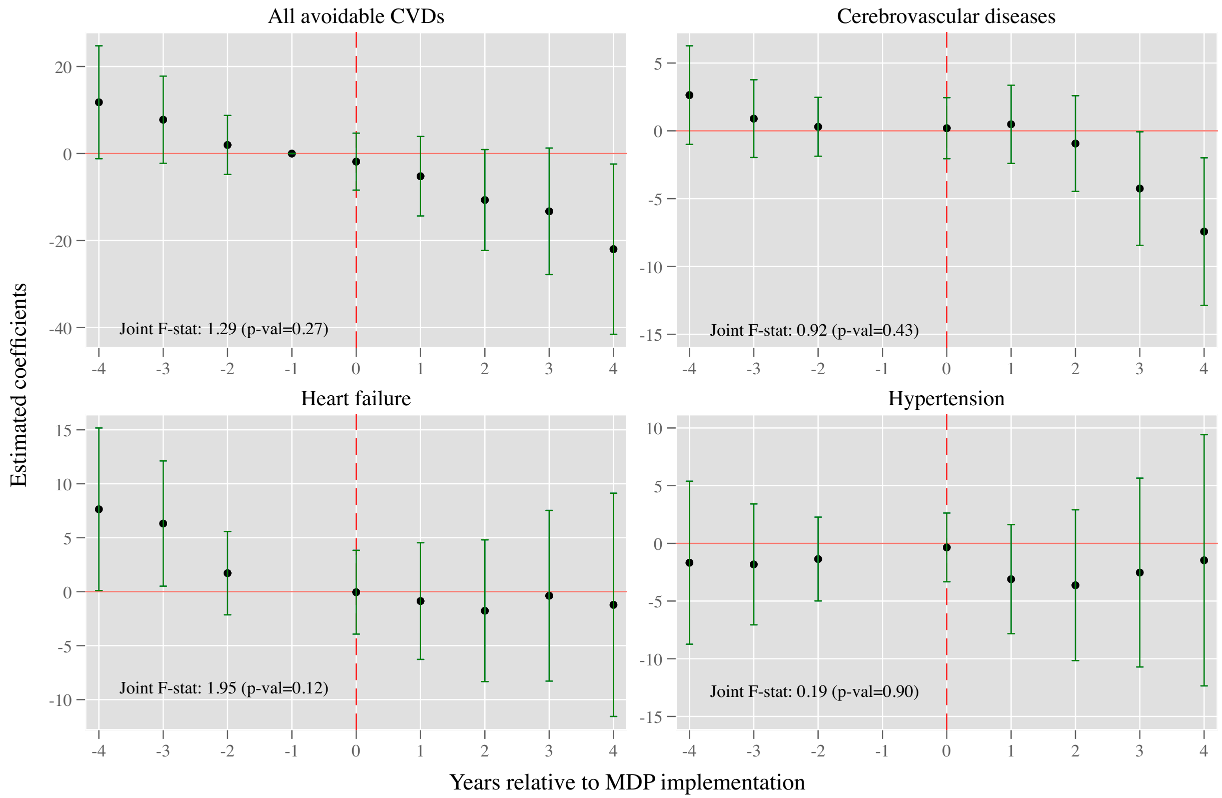

Figure 3.2 Event study for avoidable hospitalizations in the matched sample

Notes: Figure 3.2 displays the estimated coefficients and 95% confidence intervals from event study analyses for avoidable hospitalizations by place of residence per 100,000 inhabitants for each outcome variable on a continuous variable that tracks the number of years since the enrollment in MDP. The estimated coefficients are relative to the year prior to the MDP implementation. The vertical dashed line indicates the year of MDP enrollment. For period -4 to 4, the estimated coefficients are interpreted as the coefficient on 4 or more years before and 4 years since the municipality enrolled in the MDP, respectively. Data on hospitalization outcomes is based on the patient discharge records by the place of residence from the Hospital Information System of the public hospitals. CVD = Cardiovascular diseases

3.5. Discussion

In this study, we evaluated the impact of Brazil's More Doctors Program on avoidable hospitalizations for cardiovascular conditions using municipal-level data covering the period 2009-2017. We showed that the MDP was correlated with fewer hospitalizations for avoidable cardiovascular conditions, with the effects of the program increasing over time. We further found that the inverse relationship between the MDP and hospitalizations due to avoidable cardiovascular conditions was more pronounced in rural municipalities.

We found no evidence that the MDP reduced hospitalizations for heart failure and hypertension. This finding may be attributable to several factors. First, as discussed by Motala and Wyk (2019) in their recent scoping review, it may take time for international recruits to effectively practice medicine within the new health system that they joined. For instance, foreign physicians may not be familiar with treatments required for certain diseases, which do not represent an immediate public health challenge in their country of origin (Hollet *et al.* 2008; Klingler *et al.* 2016). In the case of MDP, the foreign physicians were required to attend a three-week training course upon their arrival to Brazil and before practicing medicine in their host communities. They were further required to attend medical training courses organized by Brazilian authorities at regular intervals. Yet, it is possible that it may have taken some time to get fully familiar with the disease burden in Brazil, and with how the FHS teams operationalize national guidelines for the management of chronic diseases.

It is possible that the relatively short study period (four years of MDP implementation) may not be sufficient enough time to start observing avoidable hospitalization for these conditions.

Earlier studies with much longer study periods demonstrated an inverse relationship between the FHS expansion and hospitalizations due to cardiovascular conditions. For instance, Macinko and colleagues (2010) used municipal-aggregated data for the period from 1999 to 2007 to show that there was an inverse relationship between the FHS expansion and hospitalizations due to stroke, hypertension, and other cardiovascular conditions. More recently, da Silva and Powell-Jackson (2017) concluded that the FHS expansion between 2000 and 2014 led to reductions in hospitalizations due to cardiovascular conditions, including cerebrovascular diseases, heart failure, and hypertension.

We observed substantial declines in heart failure and hypertension in the years prior to the introduction of the MDP, suggesting that the recent efforts in the management of NCDs, such as the Strategic Action Plan to Confront Noncommunicable Diseases in Brazil in 2011 may have contributed to fewer hospitalizations even before the MDP was introduced (More information on recent efforts addressing cardiovascular disease burden in Brazil is discussed in Ribeiro *et al.* 2016). However, in a recent study focusing on hypertension care continuum in Brazil, Macinko and colleagues (2018) point out that substantial challenges in hypertension control persists. Medication adherence is low (Bastos-Barbosa *et al.* 2012), even though antihypertensive medications are accessible free of charge (Harris 2012). In terms of health system factors, diagnosis and control of hypertension remain low, with approximately 38% of adults suffering from this condition are not aware of their disease status (Macinko *et al.* 2018).

Our results contribute to the literature on avoidable hospitalizations. We showed that the expansion of primary care physicians in traditionally underserved communities in Brazil led to reductions in avoidable hospitalizations for cardiovascular conditions. Our findings are in congruence with results from earlier studies (Fontes *et al.* 2018; Mattos and Mazetto 2019; Maffioli *et al.* 2019). The effects of the program were more pronounced in rural communities, where the effects were greater and became discernable earlier than in urban municipalities. These results highlight that strengthening primary care provision is a complex undertaking with important implications for other levels of the health system. However, they also suggest that the rapid recruitment of foreign physicians is not a magic bullet. We showed that even with a program that rapidly deployed a large number of foreign physicians into Brazil's health system, it took time to reap its benefits in reducing avoidable hospitalizations. Moreover, the rapid deployment of foreign physicians did not lead to measurable reductions in avoidable hospitalizations for heart failure and hypertension. The temporal nature of our findings highlights that simply adding more physicians to the health system does not guarantee rapid results for chronic conditions. We were able to observe program effects starting from the second year of implementation for cardiovascular diseases and from the third year for cerebrovascular diseases.

In recent years, a relatively rich body of literature focusing on the relationship between FHS and avoidable hospitalizations has emerged. Evidence remains mixed, and primarily based on ecological studies (Bastos *et al.* 2017). Our findings are in line with most studies that demonstrate that the scale-up of FHS led to substantial reductions in avoidable hospitalizations (Macinko *et al.* 2010; Macinko *et al.* 2011; Cavalcante *et al.* 2018). More recently, Fontes *et al.* (2018) provided causal evidence on the effect of the MDP on all avoidable hospitalizations combined; however, the authors did not provide disease-specific estimates (e.g. cardiovascular conditions). Maffioli and colleagues recently corroborated the results generated by Fontes *et al.* 2018, though they did not provide evidence on cardiovascular conditions. Mattos and Mazetto (2019) showed that the MDP led to reductions in general hospitalizations between 2010 and 2015, using a sample of 2,940 municipalities with populations of less than 500,000 inhabitants. However, the authors did not report on the extent to which the observed reductions in hospitalizations were due to ambulatory care sensitive conditions. Like Fontes *et al.* (2018) and Maffioli *et al.* (2019), we sought to provide causal evidence, and we went further by performing an in-depth analysis of the relationship between the MDP and avoidable hospitalizations for cardiovascular conditions, including cerebrovascular disease, heart failure, and hypertension.

Our study has many strengths. First, to our knowledge, this is the first study that provides a comprehensive analysis of the impact of MDP on avoidable hospitalizations for cardiovascular conditions. We made use of several publicly available datasets to build a unique municipal-aggregated dataset for 5570 municipalities covering a period of 9 years. Unlike other matching methods (i.e. propensity score matching), the coarsened exact matching allowed us to use our contextual knowledge on the criteria used by the MOH to prioritize municipalities. This was a crucial step in the selection of variables for coarsening data; the CEM yielded a study sample that was highly representative of the population, while simultaneously improving the balance in the distribution of municipal control variables. Finally, we provide new causal evidence on the differential impact of MDP between rural and urban communities.

Our study has some limitations. Health service provision in Brazil features a highly decentralized distribution of roles and responsibilities across different levels of the government. State governments have the discretion to tailor their health policies in accordance with local needs, and health personnel hiring and firing decisions are made at the municipality level. Because the federal government covered the majority of MDP expenditures, municipalities enrolling in the program incurred relatively low costs. While this funding structure was designed to remove any potential financial barriers into enrolling in MDP among resource-constrained municipalities, it may have also incentivized municipalities to substitute already practicing physicians (whose salaries were covered by municipal resources) with MDP recruits paid by the federal government. In this scenario, the MDP would simply change which doctors were practicing, rather than increase the number of physicians in a municipality. Even though participating municipalities were explicitly prohibited from firing Brazilian physicians and replacing them with MDP physicians, data are not available to capture the magnitude of potential physician substitution. Second, our estimation strategy relies on a binary measure that tracks the presence of MDP physicians in a municipality over time. While our approach allowed us to exploit the variation in uptake of the Program from 2013 to 2017, it may have limited our ability to adequately capture the main mechanisms through which the MDP impacted hospitalizations due to avoidable cardiovascular conditions. For instance, it is plausible that in municipalities that received a greater number of MDP physicians, the number of primary care consultations attended by physicians may have increased greater than those that received fewer MDP physicians. Third, our study was unable to distinguish between the control municipalities that did not have any MDP physicians because they did not apply to join the Program or those whose applications to receive MPD physicians were denied by the MOH. While Oliveira and colleagues (2016) indicated that only a small proportion of municipalities had their applications denied, we were unable to rule out any potential bias in our estimates if these two types of municipalities were systematically different from one another. Fourth, our study focused on cause-specific cardiovascular hospitalizations. However, we did not have identification codes for each patient. Therefore, we were unable to verify diagnoses and control for comorbidities, case severity or whether the hospitalization was a new case or a readmission. Fifth, while CEM successfully improved the distribution of selected observables, we observed that there were statistically significant differences in the empirical distribution of the municipal GDP per capita, hospital beds per 1,000 inhabitants and the proportion of the population above the age of 20 between the MDP and non-MDP municipalities. While we included these covariates in the regression analyses in the matched sample as suggested by Blackwell and colleagues (2009), we are unable to ascertain the remaining level of bias in our estimates in the absence of formal tests. Sixth, we observed declining trends in trends in hospitalizations due to cardiovascular and cerebrovascular diseases, as well as hypertension prior to the implementation of the MDP. While our event study suggested that the estimated coefficients in the pre-MDP period did not reach statistical significance for these conditions and joint significance tests further indicated that these coefficients were not statistically different from one another, we are unable to rule out bias in our estimates stemming from pre-trends in hospitalizations for these conditions. Seventh, we cannot rule out any potential bias in our DID estimates that may stem from a violation of the common trends assumption (Borusyak and Jaravel 2017; Goodman-Bacon 2018; Roth 2018; Callaway and Sant'Anna 2019; Bilinski and Hatfield 2019). While we conducted several sensitivity checks, we are unable to confirm whether the common trends assumption holds. Finally, the precision of our estimates may be impacted by potential errors in the coding of disease-specific ICD-10 groupings listed in the HIS. We do not expect this to be a major concern, because the HIS has consistently been shown as a reliable source of information (Mathias *et al.* 1998; Bittencourt *et al.* 2006; Bittencourt *et al.* 2008; Sgambatti *et al.* 2015).

3.6. Conclusion

Cardiovascular diseases pose a threat to population health in many countries across all income levels. With timely and appropriate provision of primary care, countries may achieve sizable reductions in hospitalizations for a range of chronic and acute health conditions, referred to as avoidable hospitalizations. Our results suggest that sizable infusion of resources in primary care provision in underserved settings can lead to gains in population health.

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Appendix

Table A3.1 Overview of covariates used in panel regressions

Data	Variables	Years	Definitions
Hospitalizations	Cerebrovascular diseases (ICD10-I63, I64, I65-69, G45), heart failure (ICD10-I50), primary hypertension (ICD10- I10), other forms of heart diseases including angina (ICD10 – I20, I23-I25) and acute myocardial infarction (ICD10- I21-I22) Injuries, poisoning and other external causes of hospitalizations (ICD-10- S00-T98)	2009-2017	Calculated as the number of hospitalizations per 100,000 inhabitants (by place of residence)
More Doctors Program introduction	Presence of MDP physicians in the municipality	2009-2017	Binary indicator (0/1) for each year indicating whether there were any More Doctors Program physicians
	Years since the introduction of the MDP	2009-2017	Continuous indicator for years since the program introduction
Socioeconomic development	Municipal GDP per capita	2009-2016	Calculated as natural logarithm of municipal GDP per person
Healthcare infrastructure	Number of hospital beds (except psychiatry beds)	2009-2017	Calculated as the number of hospital beds per 1,000 inhabitants
Private sector size	Proportion of the population with private health insurance plans	2009-2017	Calculated as a proportion by dividing municipality inhabitants by population with private health insurance plans
Population characteristics	Proportion of adult population ≥ 20 years of age Population size	2009-2015 2009-2017	Calculated as a proportion by dividing municipality population by population ≥ 20 years of age, linearly extrapolated for years 2016 and 2017 Coded as categorical variable with 5 categories: 0-4,999; 5,000-9 999;10,000-19,999;20,000-49,999; ≥50,000

Coarsened exact matching

We used coarsened exact matching method to reduce imbalances in the empirical distribution of municipal-level covariates between the MDP and non-MDP municipalities. We selected covariates and their cut-off points based on the prioritization criteria used by the MOH to rank municipalities in terms of their health needs and subsequently to distribute the MDP physicians across communities in accordance with their needs (e.g. 20% of municipal population living in extreme poverty and geographic region). For population size, we selected cut-off points used by Andrade and colleagues (2018a). Cut-off points for hospital beds per 1,000 inhabitants and proportion of adult population ≥ 20 years of age were natural breaks in the distribution of these covariates that yielded the greatest reduction in the multivariate L_1 distance, while simultaneously keeping a representative study population.

Table A3.2 Municipality level matching variables cut-off points

Domain	Variable	Categories used for CEM
Level of economic development	Percentage of population living in extreme poverty (2010)	*2 categories:* 0-20%; >20%
Local health supply	Hospital beds per 1 000 inhabitants (2012)	*3 categories:* 0-0.12.5;12.5-19.50; ≥ 19.50
Regional characteristics	Geographic region	*5 categories:* Northeast; Center-West; North; South; Southeast
Population characteristic	Proportion of population adult population ≥ 20 years of age (2012) Population size (2012)	*3 categories:* 0-0.53;0.53-0.75; ≥ 0.75 *5 categories:* 0-4,999; 5 000-9,999;10,000-19,999;20,000-49,999; ≥50,000

Notes: Data on proportion of population living in extreme poverty was extracted from the Brazil Development Atlas (2010). Data on the number of hospital beds, population age structure and population size, as well as the geographic region of each municipality, are obtained from the IBGE.

Table A3. 3 Impact of MDP on hospitalizations due to avoidable cardiovascular conditions in the matched sample

	(1)	(2)	(3)	(4)
	All avoidable CVDs	CD	HF	HP
Panel A. Controls for municipality and year fixed effects				
MDP implementation	-2.25	0.53	-0.46	0.89
	[-11.34,6.83]	[-2.01,3.07]	[-5.87,4.96]	[-3.27,5.06]
Constant	460.92	97.36	187.33	78.14
	[456.29,465.55]	[96.00,98.71]	[184.57,190.09]	[75.70,80.57]
N	50076	50076	50076	50076
R^2	0.79	0.64	0.75	0.64
Panel B. Controls municipality fixed effects, state-by-year fixed effects				
MDP implementation	-9.78	-1.38	-3.32	-0.85
	[-18.94,-0.62]	[-3.96,1.19]	[-8.75,2.11]	[-5.15,3.46]
Constant	461.19	97.48	187.41	78.47
	[456.65,465.73]	[96.14,98.81]	[184.69,190.14]	[76.14,80.80]
N	50076	50076	50076	50076
R^2	0.79	0.65	0.75	0.65
Panel C. Controls for time-varying municipality controls, municipality fixed effects, state-by-year fixed effects				
MDP implementation	-10.04	-1.41	-3.51	-0.94
	[-19.16,-0.92]	[-3.98,1.16]	[-8.91,1.89]	[-5.23,3.35]
Constant	372.52	54.32	284.86	-10.64
	[104.05,640.98]	[-20.34,128.97]	[125.63,444.09]	[-137.41,116.13]
N	50076	50076	50076	50076
R^2	0.79	0.65	0.75	0.65

Notes: All regressions are performed with CEM weights. Outcome variables are hospitalizations per 100,000 inhabitants. Data on hospitalization outcomes is based on the patient discharge records by the place of residence from the Hospital Information System of the public hospitals. Time-varying municipality characteristics include the municipal GDP per capita (in log scale), hospital beds per 1,000 inhabitants, proportion of the population with private insurance plans, proportion of adult population ≥ 20 years of age and population size. 95%CIs are in brackets. CVD: Cardiovascular diseases, CD = Cerebrovascular disease, HF = Heart failure, HY = Hypertension. All standard errors are clustered at the municipality-level.

Table A3.4 Event study point estimates for avoidable hospitalizations in the matched sample

	(1)	(2)	(3)	(4)
	All avoidable CVDs	CD	HF	HP
MDP (*Year -4)*	11.79	2.64	7.64	-1.68
	[-1.19,24.76]	[-1.00,6.27]	[0.11,15.17]	[-8.74,5.39]
MDP (*Year -3)*	7.78	0.90	6.32	-1.82
	[-2.24,17.80]	[-1.97,3.77]	[0.51,12.12]	[-7.06,3.42]
MDP (*Year -2)*	1.97	0.30	1.72	-1.36
	[-4.80,8.75]	[-1.87,2.47]	[-2.15,5.58]	[-4.99,2.28]
MDP (Year 0)	-1.86	0.20	-0.04	-0.35
	[-8.41,4.69]	[-2.05,2.45]	[-3.93,3.84]	[-3.33,2.63]
MDP (*Year 1)*	-5.21	0.48	-0.87	-3.11
	[-14.35,3.92]	[-2.40,3.37]	[-6.27,4.53]	[-7.83,1.61]
MDP (*Year 2)*	-10.68	-0.94	-1.76	-3.63
	[-22.27,0.91]	[-4.46,2.59]	[-8.33,4.80]	[-10.16,2.91]
MDP (*Year 3)*	-13.28	-4.25	-0.37	-2.53
	[-27.82,1.27]	[-8.44,-0.07]	[-8.28,7.54]	[-10.71,5.65]
MDP (*Year 4)*	-21.97	-7.43	-1.21	-1.47
	[-41.54,-2.40]	[-12.86,-1.99]	[-11.56,9.13]	[-12.35,9.42]
Constant	366.65	53.04	280.18	-9.61
	[99.22,634.07]	[-21.51,127.58]	[121.21,439.15]	[-135.87,116.65]
N	50076	50076	50076	50076
R^2	0.79	0.65	0.75	0.65

All regressions are performed with CEM weights. Outcome variables are hospitalizations per 100,000 inhabitants. Data on hospitalization outcomes is based on the patient discharge records by the place of residence from the Hospital Information System of the public hospitals. Time-varying municipality characteristics include the municipal GDP per capita (in log scale), hospital beds per 1,000 inhabitants, proportion of the population with private insurance plans, proportion of adult population ≥ 20 years of age and population size. 95%CIs are in brackets. CVD: Cardiovascular diseases, CD = Cerebrovascular disease, HF = Heart failure, HY = Hypertension. All standard errors are clustered at the municipality-level.

Additional Robustness Checks

<u>Sensitivity Check I:</u>

Our DID estimates rely on the assumption that in the absence of the MDP, the trends in hospitalization rates between treatment and control municipalities would have remained similar over time (i.e., common trends assumption). To check this assumption, we, first, visually examined whether trends in avoidable hospitalization outcomes were similar across municipalities in the post-CEM sample. We stratified the key outcome variables between MDP and non-MDP municipalities for the period 2009-2017.

Figure A3.1 presents trends in avoidable hospitalization outcomes. The average number of avoidable hospitalizations for cardiovascular diseases declined from 453 to 419 per 100,000 inhabitants. Conversely, there was an increasing trend in hospitalizations for cerebrovascular diseases from 97 to 110 per 100,000 inhabitants. Hospitalizations for heart failure and hypertension also declined in the study period, from 183 to 135, and 77 to 43 per 100,000 inhabitants, respectively. We observed similar trends across in avoidable hospitalization outcomes across municipalities enrolled in the MDP and control municipalities prior to the launch of the program in 2013.

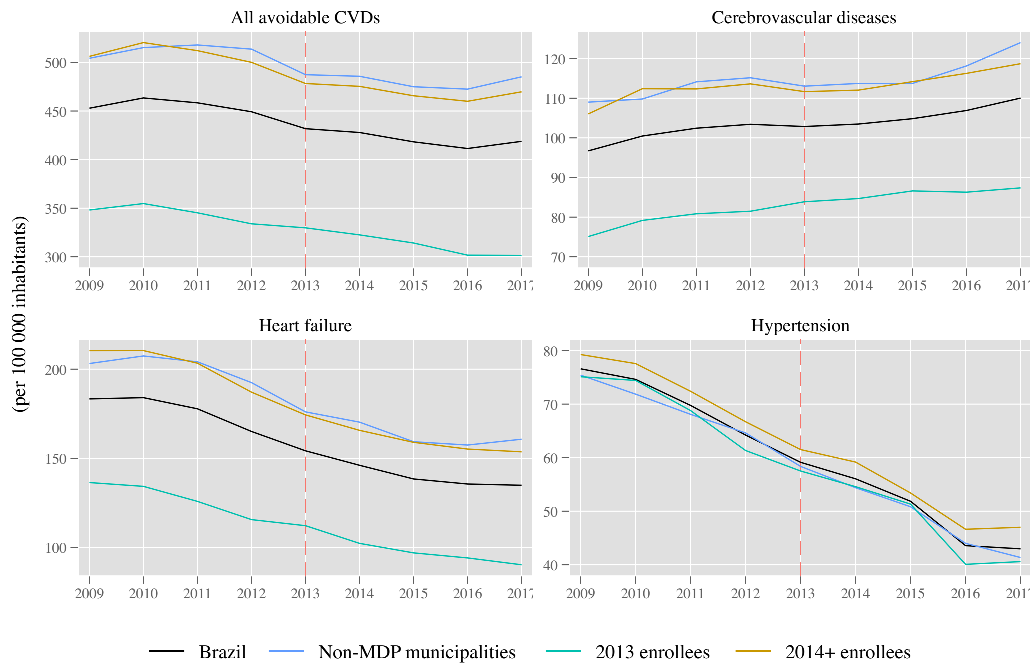

Figure A3. 1 Avoidable hospitalizations by place of residence per 100,000 inhabitants for cardiovascular conditions by the year of enrolment in MDP in post-CEM sample, 2013-2017

Notes: We combined all municipalities enrolled in the program after 2014 for visual ease, because the majority of municipalities enrolled in the MDP in the first two years of its implementation. Data is based on the patient discharge records by the place of residence from the Hospital Information System of the public hospitals. The dotted line in 2013 represents the year in which the MDP was launched in Brazil. CVD = Cardiovascular diseases

Sensitivity Check II:

We re-estimate Equations 1 and 2 with a more conservative sample, using a subset of municipalities that were continuously enrolled in the MDP throughout the study period with no disruptions in enrollment. Table A3.5 shows that the substantive results for estimating the average treatment effects of the program remain robust, though the magnitude of the most estimated coefficients on MDP was slightly smaller compared to the estimates presented in Tables 3.2 and 3.3. For continuous implementers, we see that the reductions in hospitalizations for cardiovascular diseases and cerebrovascular disease are observed in the second and fourth years after the MDP was introduced, respectively. Similar to our earlier findings, the magnitude of the estimated coefficient on MDP for cardiovascular diseases grew over time.

Table A3.5 Impact of the MDP on avoidable hospitalizations using a subset of municipalities that were continuously enrolled in the program

	(1) All avoidable CVDs	(2) CD	(3) HF	(4) HP
Panel A				
MDP	-10.53	-0.91	-3.72	-1.25
	[-20.10,-0.96]	[-3.59,1.77]	[-9.35,1.91]	[-5.80,3.30]
Constant	499.22	90.41	336.24	10.64
	[219.16,779.28]	[14.64,166.18]	[179.70,492.79]	[-124.73,146.00]
N	43515	43515	43515	43515
R^2	0.80	0.66	0.75	0.67
Panel B				
MDP (Year 0)	-6.97	-0.22	-3.30	-0.42
	[-15.10,1.15]	[-2.76,2.31]	[-8.11,1.50]	[-4.20,3.35]
MDP (*Year 1)*	-9.65	0.73	-3.72	-2.85
	[-20.47,1.17]	[-2.37,3.84]	[-10.14,2.69]	[-8.11,2.40]
MDP (*Year 2)*	-14.52	-1.18	-4.40	-2.37
	[-27.38,-1.66]	[-4.90,2.55]	[-11.89,3.10]	[-8.68,3.94]
MDP (*Year 3)*	-16.15	-4.24	-4.07	-0.36
	[-31.34,-0.96]	[-8.55,0.08]	[-12.84,4.70]	[-7.78,7.05]
MDP (*Year 4)*	-22.85	-7.51	-4.15	1.39
	[-43.18,-2.52]	[-13.12,-1.89]	[-15.17,6.87]	[-9.18,11.97]
Constant	501.11	91.26	336.34	10.47
	[221.23,780.98]	[15.55,166.96]	[179.74,492.95]	[-124.94,145.88]
N	43515	43515	43515	43515
R^2	0.80	0.66	0.75	0.67

Notes: All regressions are performed with CEM weights. Outcome variables are hospitalizations per 100,000 inhabitants. Data on hospitalization outcomes is based on the patient discharge records by the place of residence from the Hospital Information System of the public hospitals. Time-varying municipality characteristics include the municipal GDP per capita (in log scale), hospital beds per 1,000 inhabitants, proportion of the population with private insurance plans, proportion of adult population ≥ 20 years of age and population size. 95%CIs are in brackets. CVD: Cardiovascular diseases, CD = Cerebrovascular disease, HF = Heart failure, HY = Hypertension. All standard errors are clustered at the municipality-level.

Sensitivity Check III:

Next, we evaluate whether the MDP enrollment coincided with any changes in health resources allocated for hospital care. The rationale for this analysis is that the enrollment in MDP may have led municipalities to shift the composition of investments to health across primary, secondary and tertiary care. Table A3.6 shows that the MDP implementation had no impact on the number of general hospitals per 1,000 inhabitants or hospital beds per 1,000 inhabitants.

Table A3.6 Impact of the MDP on health infrastructure

	(1)	
	General hospitals per 1000 inhabitants	Hospital beds per 1000 inhabitants
Panel A		
MDP	0.00	0.01
	[-0.00,0.00]	[-0.02,0.04]
Constant	0.02	0.84
	[-0.01,0.06]	[-0.08,1.77]
N	50076	50076
R^2	0.92	0.93
Panel B		
MDP (Year 0)	0.00	0.01
	[-0.00,0.00]	[-0.02,0.03]
MDP (*Year 1*)	0.00	0.02
	[-0.00,0.00]	[-0.02,0.05]
MDP (*Year 2*)	0.00	0.02
	[-0.00,0.00]	[-0.02,0.06]
MDP (*Year 3*)	0.00	0.03
	[-0.00,0.00]	[-0.02,0.08]
MDP (*Year 4*)	0.00	0.03
	[-0.00,0.00]	[-0.03,0.09]
Constant	0.02	0.84
	[-0.01,0.06]	[-0.08,1.77]
N	50076	50076
R^2	0.92	0.93

Notes: All regressions are performed with CEM weights. Data on hospital infrastructure is based on TABNET system of the public hospitals. 95%CIs are in brackets. Time-varying municipality characteristics include the municipal GDP per capita (in log scale), proportion of the population with private insurance plans, proportion of adult population ≥ 20 years of age and population size. All standard errors are clustered at the municipality-level.

Sensitivity Check IV:

Next, we perform a test to ascertain whether there were statistically significant differences in key hospitalization outcomes between the MDP and non-MDP municipalities prior to the launch of the program, using data from 2009-2012. We re-estimate Equation 1, using the same set of control variables and include an interaction between a dummy variable that tracks whether a municipality ever enrolled in the MDP and a linear time trend. As shown in Table A3.7, we do not find statistically significant differences in hospitalization trends between MDP and non-MDP municipalities prior to the implementation of MDP, conditional on time-varying municipal level controls.

Table A3.7 Test of equality of pre-MDP trends between MDP and non-MDP municipalities

	(1)	(2)	(3)	(4)
	All avoidable CVDs	CD	HF	HP
Interaction of time and ever enrolled in MDP	-5.55	-1.07	-2.57	-1.03
	[-11.31,0.20]	[-2.86,0.72]	[-5.95,0.82]	[-3.91,1.85]
Constant	67.55	-80.29	88.45	-79.47
	[-560.95,696.05]	[-277.54,116.96]	[-312.36,489.27]	[-368.62,209.69]
N	22256	22256	22256	22256
R^2	0.88	0.77	0.86	0.81

Notes: All regressions are performed with CEM weights. Outcome variables are hospitalizations per 100,000 inhabitants. Data on hospitalization outcomes is based on the patient discharge records by the place of residence from the Hospital Information System of the public hospitals. 95%CIs are in brackets. Time-varying municipality characteristics include the municipal GDP per capita (in log scale), hospital beds per 1,000 inhabitants, proportion of the population with private insurance plans, proportion of adult population ≥ 20 years of age and population size. CVD: Cardiovascular diseases, CD = Cerebrovascular disease, HF = Heart failure, HY = Hypertension. All standard errors are clustered at the municipality-level.

Falsification Test I:

Our first falsification test exploits the information on hospitalization types that are not sensitive to primary care. For this exercise, we repeat our analysis for hospitalizations per 100,000 inhabitants due to injuries, poisoning and other external causes of hospitalizations. Because the FHS teams do not provide health services that can lead to any discernable changes for this cause of hospitalization, we do not expect to observe any measurable impact of the MDP. As shown in Table A3.8, the estimated coefficient on the MDP is not statistically different from zero.

Table A3.8 Impact of the MDP on hospitalizations due to injuries, poisonings and other external causes

	(1)
	Injuries, poisoning and other external causes
Panel A	
MDP	-2.90
	[-10.86,5.07]
Constant	129.92
	[-135.20,395.03]
N	50076
R^2	0.75
Panel B	
MDP (*Year 0)*	-3.08
	[-10.19,4.03]
MDP (*Year 1)*	-0.30
	[-9.58,8.98]
MDP (*Year 2)*	-1.57
	[-12.67,9.54]
MDP (*Year 3)*	-7.27
	[-20.54,6.00]
MDP (*Year 4)*	-10.64
	[-30.42,9.13]
Constant	130.60
	[-134.47,395.67]
N	50076
R^2	0.75

Notes: All regressions are performed with CEM weights. Outcome variables are hospitalizations per 100,000 inhabitants. 95%CIs are in brackets. Time-varying municipality characteristics include the municipal GDP per capita (in log scale), hospital beds per 1,000 inhabitants, proportion of the population with private insurance plans, proportion of adult population ≥ 20 years of age and population size. All standard errors are clustered at the municipality-level.

Falsification Test II:

In our second falsification test, we test whether the estimated MDP average treatment effect remains robust if we randomly assign placebo MDP enrollment years to municipalities. We re-estimate Equation 1 by replacing the actual year in which a municipality is first enrolled in the MDP with a randomly assigned placebo year between 2013 and 2017. No municipality is assigned their actual year of enrollment. We repeat this simulation 500 times and plot the density distribution function of the estimated coefficients with placebo MDP implementation dates.

Figure A3.2 plots the density distribution function of the estimated coefficients with placebo MDP implementation dates. Our results show that the distribution of the placebo MDP coefficient is centered around zero, and our estimated MDP coefficient is outside the range of placebo coefficients. This finding suggests that the reduction in avoidable hospitalizations for cardiovascular disease is associated with the precise MDP enrollment timeline across municipalities. Taken together, we interpret these findings as further evidence to allay concerns over potential endogeneity.

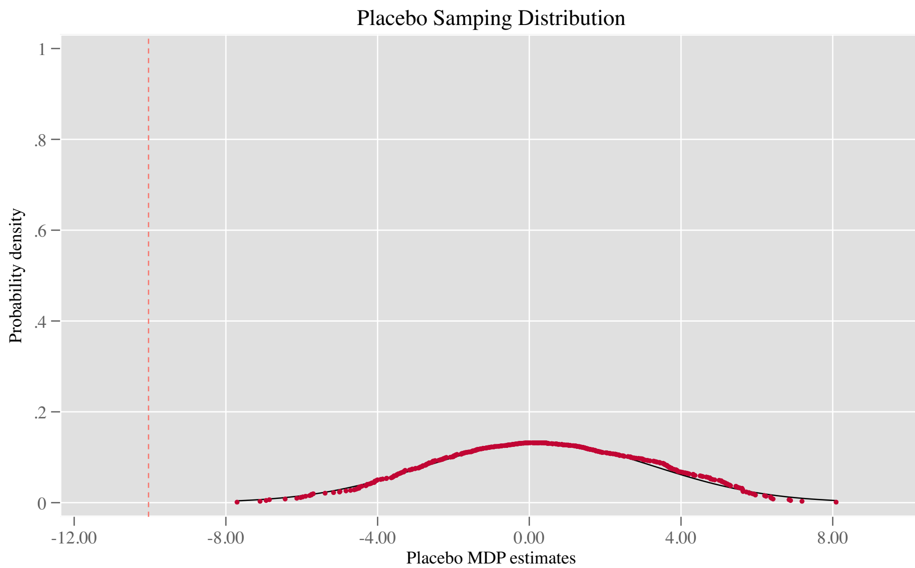

Figure A3. 2 Density probability distribution of the placebo MDP exposure on avoidable hospitalizations for cardiovascular diseases per 100,000 inhabitants

Notes: Red dashed line is the true MDP effect. Data is based on the patient discharge records by the place of residence from the Hospital Information System of the public hospital

Additional analysis – by MDP vulnerability designation

As an additional analysis, we examined heterogenous treatment effects by MDP vulnerability designation. For this analysis, we divided municipalities into two groups. In line the classifications developed in Chapter 2, municipalities that adhered to at least one of MDP's vulnerability criteria during the study period were classified as ever-targeted. Municipalities that did not fit any of the vulnerability criteria were considered non-target. As shown in Table A3.9, none of the estimated MDP coefficients reach statistical significance, even though there is an inverse relationship between the MDP and most avoidable hospitalizations due cardiovascular conditions.

Table A3.9 Impact of the MDP on avoidable hospitalizations by vulnerability designation

	(1)	(2)	(3)	(4)
	All avoidable CVDs	CD	HF	HP
Panel A: Ever-targeted municipalities				
MDP	-9.64	-1.97	-1.06	-3.71
	[-20.28,1.01]	[-4.82,0.88]	[-7.15,5.03]	[-9.43,2.00]
Constant	388.08	47.13	330.45	-36.68
	[27.67,748.48]	[-48.59,142.85]	[131.37,529.52]	[-229.50,156.13]
N	33498	33498	33498	33498
R^2	0.78	0.66	0.75	0.66
Panel B: Non-target municipalities				
MDP	-7.89	-0.73	-8.83	5.16
	[-25.95,10.17]	[-6.14,4.67]	[-20.03,2.37]	[-1.43,11.74]
Constant	950.26	204.89	397.19	81.09
	[641.89,1258.62]	[103.41,306.36]	[208.80,585.58]	[-3.94,166.12]
N	16578	16578	16578	16578
R^2	0.75	0.58	0.73	0.63

Notes: We group municipalities into two categories based on their vulnerability designation status in MDP. More information on vulnerability designations are in Chapter 2. The key explanatory variable is a binary indicator that takes value 1 if there is at least one MDP physician serving at the municipality starting from the first year of enrollment in MDP and zero otherwise. Hospitalization data are extracted from the Hospital Information System of the public hospitals using ICD-10 groupings indicated in patient discharge records. All regressions include municipality fixed effects and state-time fixed effects. Time-varying municipality controls include municipal GDP per capita (in log scale), hospital beds per 1,000 inhabitants, proportion of the population with private insurance plans, proportion of adult population ≥ 20 years of age and population size. All regressions include CEM weights. In all regressions, standard errors are clustered at the municipality level.

Chapter IV:

Does expanding access to primary care physicians reduce child and adolescent hospitalizations?

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Abstract

Introduction. Primary care is hypothesized to improve child and adolescent health by improving the monitoring, prevention, and treatment of health conditions, providing greater access to healthcare services, addressing social determinants of health and reducing health disparities. Yet, empirical evidence from developing countries comes primarily from ecological studies. To address this gap, we evaluate the impact of Brazil's More Doctors Program (MDP) on hospitalizations due to avoidable causes among children and adolescents under 20 years of age.

Data and Methods. We built a longitudinal dataset by linking municipal level data from the Hospital Information System, the Ministry of Health, the Brazilian Regulatory Agency and the Institute of Geography and Statistics from 5,570 municipalities for the years 2009 to 2017. We used coarsened exact matching and difference-in-difference methods in order to establish causal inference. Outcome variables were hospitalizations due to all avoidable causes, including asthma, infectious gastroenteritis, and pneumonia, per 10,000 children and adolescents under 20 years of age, as well as the number of primary care visits for this age group.

Results. Our descriptive findings show that during the study period, the decline in avoidable hospitalizations was about 4 times that of the decline in all-cause hospitalizations. Reductions in asthma-related hospitalizations reached almost 52%, followed by 39% for pneumonia- and 37% for infectious gastroenteritis-related hospitalizations. The gap in all-cause avoidable hospitalizations between urban and rural municipalities narrowed, though hospitalizations remained slightly higher in rural municipalities. We find that while there was an inverse relationship between the MDP and avoidable hospitalizations, the MDP did not reduce hospitalizations due to avoidable causes for the study sample, with an estimated impact of -1.84 (95%CI: -5.34, 1.66). For rural municipalities, the estimated MDP coefficient was -7.43 (95%CI: -13.20, -1.65), compared to 1.23 (95%CI: -3.16,5.61) in urban municipalities. Decomposing our results by health condition indicated that in rural

municipalities, the MDP led to 3.63 (95%CI: -6.65,-0.61) fewer hospitalizations due to infectious gastroenteritis, though it did not change hospitalization due to asthma and pneumonia, with estimated coefficients of -1.68 (95%CI: -3.43,0.07) and -0.26 (95%CI: -3.47,2.94) respectively. Finally, we also show that the MDP increased primary care consultations by 7% (95%CI: 0.04, 0.10).

Conclusions. Our results highlight that increasing access to primary care physicians in underserved communities contributed to the narrowing of urban-rural disparities in hospitalizations.

4.1. Introduction

Primary care is hypothesized to improve child and adolescent health by improving the monitoring, prevention and treatment of diseases (e.g., vaccinations), providing greater access to tertiary and secondary care services (e.g., medical referrals), addressing social determinants of health (e.g., health education and promotion, water, and sanitation) and reducing health disparities (WHO 2008; Hone *et al* 2017a; Hone *et al* 2018). A body of literature consistently underscores that countries with stronger primary care orientation are more likely to improve population health (Macinko *et al.* 2003; Starfield *et al.* 2005; Macinko *et al.* 2009; Friedberg *et al.* 2010; Kruk *et al.* 2010; Kringos *et al.* 2013), achieve improvements in the quality and efficiency of service delivery (Kringos *et al.* 2010), and reduce the need for hospitalization and use of emergency services (Shi 2012; Huntley *et al.* 2014), while narrowing health disparities (Shi *et al.* 2005; Starfield *et al.* 2005; Starfield 2012). Yet, health systems in many low- and middle-income countries remain hospital-centric (Hone *et al.* 2018).

The 2008 World Health Organization Report on Primary Health Care highlighted the importance of strengthening primary care to ensure progress towards universal health coverage goals (WHO 2008). Subsequently, the 2018 Astana Declaration (Alma-Ata 2.0) reinvigorated global commitment into investments for primary care (WHO 2018). For children and adolescents, greater access to primary care has been shown to reduce mortality (Shi *et al.* 2004; Russo *et al.* 2019), the need for hospitalizations (Cecil *et al.* 2015), unplanned hospitalizations (Cecil *et al.* 2018), and utilization of emergency care services (Christakis *et al.* 2001; Brousseau *et al.* 2007). Studies that focus on specific health conditions provide further evidence that greater access to primary care is inversely associated with hospitalizations for conditions sensitive to primary care (Flores *et al.*2003; *Tom et al.*2010; Medford-Davis *et al.*2016; Cecil *et al.* 2018; Coller *et al.* 2018; Zucco *et al.*2019), including asthma (Flores *et al.* 2005; Utidjian *et al.*2017), diarrhea (Roncalli *et al.*2006; Gao *et al.*2018) and pneumonia (Emery *et al.* 2015; Pina *et al.* 2017). Despite the policy interest, empirical evidence on the contribution of primary care on child and adolescent health in developing countries comes primarily from ecological studies. Most studies report average treatment effects, which may mask important differences in the contributions of primary care across communities with diverse health needs.

To address these gaps in the literature, we examine the impact of Brazil's More Doctors Program (MDP) on hospitalizations among Brazilian children and adolescents under 20 years of age. Similar to many developing countries, Brazil faces considerable challenges in access to healthcare services (Massuda *et al.* 2018). Primary care services are delivered through the Family Health Strategy (FHS) Program, which provides free-of-charge healthcare to more than 122 million Brazilians (Macinko and Harris 2015). The FHS scale-up over the last two decades has been rapid, but heterogeneous (Andrade *et al.*2018a; Andrade *et al.*2018b). The geographic imbalances in the distribution of physicians have been among the most difficult challenges hindering the expansion of FHS (Scheffer 2013; Andrade *et al.*2018b). To address this challenge, the Ministry of Health (MOH) introduced a supply-side intervention called the More Doctors Program (MDP) in 2013. Through the MDP, the MOH recruited a cadre of foreign and Brazilian physicians to serve in communities where previous attempts at attracting Brazilian physicians have proven difficult.

Our main hypothesis is that the considerable infusion of health-resources through the MDP to traditionally underserved Brazilian municipalities over the period between 2013 and 2017 reduced the need for hospitalizations among children and adolescents under 20 years of age. We exploit the geographic variation in the uptake of the MDP to estimate its causal impact by employing coarsened exact matching and difference-in-difference methods in conjunction. We disaggregate our results by type of location (i.e., rural vs. urban) to study the heterogeneous treatment effects and explore potential pathways that may explain our main findings.

The remainder of the paper is organized as follows. Section 4.2 provides background on the organization of primary care services in Brazil and the MDP. Section 4.3 describes the study sample, sources of data used in the empirical analysis, and statistical analysis. Section 4.4 reports results on the impact of MDP on primary care consultations and hospitalization rates among children and adolescents under 20 years of age and sensitivity checks. Section 4.5 discusses the implication of our findings and Section 4.6 concludes.

4.2. Study setting

Since 1994, primary care provision in Brazil is organized through a community-based service delivery platform called the FHS. The FHS relies on multi-professional health teams that consist of physicians, nurses and community health workers. FHS teams are tasked with providing a wide array of preventive care services for up to 1,000 households in their geographically non-overlapping service areas (Andrade *et al.*2018a). FHS teams typically provide maternal and childcare, health education and promotion services, monitor and manage communicable and chronic diseases, organize community outreach programs and immunization campaigns.

Empirical evidence, though generated mostly through ecological study designs, demonstrated that the expansion of the FHS has benefited population health over the last two decades (Victora *et al.* 2011; Paim *et al.*2011; França *et al.*2016; Bastos *et al.*2017; Castro *et al.*2019) through reductions in child and adult mortality (Macinko *et al.*2006; Macinko *et al.*2007; Aquino *et* *al.*2009; Rocha and Soares 2010; Rasella *et al.*2010), amenable mortality (Hone *et al.*2017b), hospitalizations due to health conditions considered sensitive to primary care (Macinko *et al.* 2009; Macinko *et al.*2010; Macinko *et al.*2011), and reductions in health disparities (Victora *et al.*2000; Macinko and Lima-Costa 2012; Hone *et al.*2017a).

The FHS scale-up over the last two decades has been rapid and uneven, with the proportion of the population covered by FHS in each municipality varying by population size, level of socioeconomic development, and geographic region (Andrade *et al.*2018a; Andrade *et al.*2018b; Castro *et al.*2019). Geographic disparities in physician availability have been consistently highlighted as a key challenge impeding the further expansion of the FHS (Scheffer 2013; Andrade *et al.*2018b).

The MDP was launched by the MOH in 2013 with the aim of strengthening primary care provision in Brazil's underserved communities that typically faced difficulties attracting and retaining physicians. The MOH recruited Brazilian and foreign physicians to work in the municipalities for a span of 3 years. The MDP physician contracts were renewable and offered competitive salaries. Foreign physicians were required to have prior experience in family medicine and were exempted from taking the national test that all Brazilian and non-MDP foreign physicians are required to pass before they could practice medicine in Brazil. Instead, the foreign MDP recruits were enrolled in a mandatory three-week training course prior to their placement in their assigned posts and attended medical training courses organized by the Brazilian officials. They could also enroll in online training courses. Each MDP physician was assigned a supervisor, a Brazilian medical professional with experience in primary care. The MDP physicians were allowed to practice medicine only within the organization of the FHS. Municipalities had the discretion to place them within the existing FHS teams that were already working in the community or form new FHS teams with the MDP physicians. The MOH organized the MDP enrollment process through routine public calls that invited municipalities to join the program. All municipalities were eligible to request MDP physicians. While distributing the MDP physicians, the MOH prioritized municipalities with the highest level of poverty, the lowest levels of socioeconomic development and municipalities located in the North and Northeast regions (Chapter 2 provides a detailed discussion of the municipality prioritization process and the geographic expansion of the MDP from 2013 to 2017).

4.3. Methods

4.3.1. Data and study sample

Our matched sample included 50,076 observations from 5,564 out of 5570 municipalities between the period 2009-2017. We assembled a longitudinal dataset by merging municipal-level data from the Hospital Information System (HIS) of the Unified Health System, MOH, the Brazilian Regulatory Agency and the Brazilian Institute of Geography and Statistics (IBGE).

We focused on two sets of outcomes. First, we examined the impact of MDP on primary care sensitive conditions, also referred to as avoidable hospitalizations, among children and adolescents. We selected the list of all-cause avoidable hospitalization based on the list of primary care sensitive conditions published by the MOH in 2008 (MOH 2008), as well as Fontes and colleagues (2018) that earlier examined the impact of MDP on avoidable hospitalizations. In Brazil, these conditions are considered to reflect the disease burden and the organization of primary care services within the country context and used as a measure to track health system performance over time (Macinko *et al.* 2011).

We measured hospitalization rates in each municipality by dividing the number of avoidable hospitalizations for children and adolescents under 20 years of age by the number of inhabitants in each municipality in this age group and multiplying it by 10,000 using data from two publicly available datasets. First, we extracted electronic patient records from the HIS by the place of residence and age group. The HIS is a national administrative database that collates patient records for all hospitalizations financed by the Unified Health System (UHS), including public hospitals, private and non-profit facilities paid by the UHS (The HIS covers approximately 70% of all hospitalizations annually). For each condition, we extracted data from the HIS using the ICD-10 groupings (The HIS switched from ICD-9 to ICD-10 groupings in 1999, and used the latter to classify hospitalizations occurring thereafter [Macinko *et al.* 2011]). Table A4.1 in Appendix lists ICD-10 groupings by disease condition. We combined the HIS records with population estimates on the number of people under 20 years of age in each municipality. Population estimates by age were available only for the years 2009 to 2015 (Ministério da Saúde 2019). Since no substantial changes were observed in the age structure during the period, the calculation of the age distribution of municipalities for the years 2016 and 2017 used the 2015 age distribution of municipalities.

Next, we analyzed hospitalizations due to a subset of avoidable causes, including asthma, infectious gastroenteritis, and pneumonia (Table A4.2 presents a list of actions that can be taken at primary care settings). While Brazil reduced the disease burden of conditions we selected, they continue to disproportionately affect children and adolescents residing in communities with lower levels of socioeconomic development (Thörn *et al.* 2001; Andrade *et al.* 2004; Rasella *et al.* 2010; Escobar *et al.* 2015; Cardosa *et al.* 2017; Wehrmeister *et al.* 2019).

We then turned our attention to the mechanisms by which primary care can reduce the need for hospitalizations. Starfield (1998) suggests that an important feature of primary care is its ability to serve as the first point of contact with the health system before patients seek care elsewhere. In our study, we examined whether the MDP led to any increases in the number of primary care consultations for children and adolescents as a proxy for first-contact care. We obtained data from the MOH Information System on Primary Care (SIAB) website for the period from 2009-2015 (For the year 2015, SIAB includes data until the month of July because this database was discontinued thereafter [MOH, 2014]). We limited our analysis to 5,441 municipalities that routinely reported data on the number of primary care consultations by age group in the study period.

We controlled for several time-varying economic, demographic and health system characteristics of municipalities. We extracted data from the MOH on the number of hospital beds using July as our reference month, because the data were available on a monthly basis, as was done in earlier studies (Andrade *et al.* 2018a; Andrade *et al.* 2018b). We obtained municipal GDP per capita from the IBGE website for 2009-2017 and adjusted it for inflation. We extracted data on the proportion of the population with private insurance plans between 2009-2017 from the Brazilian Regulatory Agency website. We extracted data from the IBGE website on the population size of each municipality between 2009-2017, which we categorized as: 0-4,999; 5,000-9,999; 10,000-19,999; 20,000-49,999; ≥50,000 inhabitants, as was done in earlier studies (Andrade *et al* 2018a). We also controlled for the proportion of the adult population at 20 years of age and above as a measure of demographic characteristics using data obtained from the IBGE. Finally, we obtained the list of municipalities with populations residing in rural settlements in accordance with the November 2013 Report of the Board of Land Procurement and Settlement Projects of the Ministry of Agrarian

Development. We classified municipalities with no rural settlements as urban municipalities (IBGE 2017).

4.3.2. Statistical analysis

Our main estimation challenge stems from the non-random enrollment in the MDP because the municipalities were required to act proactively by submitting an online request to the MOH. While the application process was designed to ensure a fast and easy enrollment process with clear instructions for municipal administrators. However, it may have also deterred them from joining the program if municipal officials considered this process to be a bureaucratic hurdle. To address this concern, we used coarsened exact matching (CEM) and difference-in-difference (DID) methods in conjunction. By using CEM, we aimed to reduce imbalances in the distribution of municipal level controls that may correlate with hospitalization rates between treatment and control municipalities. (Other advantages of CEM are discussed in detail elsewhere [Blackwell *et al* 2009; King *et al* 2011; Iacus *et al* 2012]).

Similar to Chapter 3, we started out by defining the treatment municipalities as those that had at least one MDP physician working in the community and control municipalities as those that did not have any MDP physician during the study period. Next, we matched treatment and control municipalities based on the set of criteria the MOH used to distribute the MDP physicians across communities (i.e. the level of socioeconomic development, geographic location and population characteristics). Additionally, we included covariates for the proportion of the population aged 20 years or more to account for the age distribution in each municipality. After confirming that this procedure yielded a more balanced empirical distribution of covariates, we proceeded to perform difference-in-difference analyses to estimate the following linear model specification:

$$Y_{it} = \beta_0 + \beta_1 MDP + \beta_2 X_{it} + \varphi_i + \rho_{st} + \varepsilon_{ij}$$

Where Y_{it} was the hospitalization or primary care utilization outcomes for municipality *i* in year *t*. Our key measure of exposure, MDP, was a binary variable that takes the value of one starting from the first year in which there was at least one MDP physician serving in a municipality, and zero otherwise. We adopt this approach, because the effects of MDP may have endured even after the program physicians left their host communities. This is a plausible assumption for several reasons. First, the MDP physicians and other members of the FHS teams may have learned different approaches to practicing community-based primary care from each other, which may have altered the ways in which the FHS teams interacted with their patients. Alternatively, the FHS physicians may have contributed to the health education and promotion activities that the FHS teams typically organize in host communities, which may lead to behavioral changes among community members that may endure even after the MDP physicians left their host communities (Clement *et al.* 2009; Taggart *et al.* 2012).

We included a vector of time-varying municipality characteristics, X_{it}, which may correlate with hospitalizations among children and adolescents. We included municipality-fixed effects, φ_i, to account for time-invariant characteristics across municipalities (e.g. geographic, cultural or historical factors). Finally, we included state-time fixed effects, ρ_{st}, to account for state-level public policies. All regressions included weights generated by CEM. We clustered all standard errors are at the municipality-level. We further explored heterogeneous treatment effects by type of residence, and by the level of FHS coverage at baseline (Results from the latter analysis are presented in the Appendix).

We performed several robustness checks. First, we examined the pre-existing trends in our study outcomes by replacing our main MDP exposure variable with a continuous indicator that tracked the years relative to the year prior to the enrollment in MDP in each municipality. This approach allowed us to ascertain whether the observed changes in our study outcomes coincided with the MDP implementation. We further performed joint significance tests to investigate whether the estimated pre-trend coefficients were statistically different from one another. Third, we plotted hospitalization rates for each health condition by MDP enrollment year to examine whether the parallel trends assumption required for the difference-in-difference method was satisfied (Ryan *et al.* 2015). We also examined whether there were statistically significant declines in hospitalization rates in years prior to the MDP roll-out between MDP and non-MDP municipalities. To examine whether our assumption regarding the enduring effects of the MDP, we repeated our analysis using a subset of municipalities that were continuously enrolled in the MDP with no disruptions in their program enrollment status from 2013 to 2017. As another robustness check, we investigated whether the MDP was associated with any changes in hospitalizations due to non-avoidable causes. We expected that the MDP had no effect on hospitalizations for these conditions as they are not considered to be sensitive to primary care. Finally, we re-calculated hospitalization rates by replacing the 2015 age structure values with the growth rate of the children population under 20 years of age between 2014-2015 to ascertain whether our results remained robust to the scaling of hospitalization rates (Further details are provided in the Appendix).

4.4. Results

Table 4.1 presents trends in hospitalization rates by health conditions, the number primary care consultations per 10,000 children and adolescents, and municipality characteristics from 2009 to

2017. From 2009 to 2017, all avoidable hospitalizations accounted for 23% of all hospitalizations. We observe declining trends in all hospitalization outcomes in the years prior to the nationwide launch of the MDP in 2013. During the study period, the decline in hospitalizations due to all avoidable conditions (29%) was about four times that of the decline for all-cause hospitalizations (7%). Reductions in asthma-related hospitalizations reached almost 52%, followed by 39% for pneumonia- and 37% for infectious gastroenteritis-related hospitalizations. All observed changes in hospitalization rates were statistically significant. We also found that there were statistically significant increases in municipal income, the proportion of the population with private plans, and the proportion of the population aged 20 or more. Conversely, the number of hospital beds per 1,000 inhabitants declined.

Table 4.2 presents the impact of MDP on hospitalization rates per 10,000 children and adolescents under 20 years of age. In Panel 1, we present models that include controls only for municipality and year fixed effects. The estimated MDP coefficients were negative for all study outcomes except for pneumonia. None of them reached statistical significance. In Panel 2, we introduce state-by-year fixed effects. In these models, all of the estimated coefficients on MDP remained negative, though they were smaller in magnitude. In Panel 3, we added time-varying municipality fixed effects. We found that the estimated MDP coefficient was -1.84 (CI95%: -5.34,1.66) for avoidable hospitalizations. Disaggregating results by health condition showed that the estimated MDP coefficients were -0.99 (CI95%: -2.07,0.10) for asthma, -0.11 (CI95%: -1.76,1.55) for infectious gastroenteritis, and -0.92 (CI95%:-2.85,1.00) for pneumonia. These results indicated an inverse relationship between the MDP and hospitalization rates. However, none of the estimated coefficients were statistically different than zero.

Table 4.1 Trends in hospitalization rates per 10,000 children and adolescents <20 years of age and municipality characteristics in the matched sample, 2009-2017

Characteristics	**2009**		**2017**		**Trends between 2009-2017**		
	Mean	**SD**	**Mean**	**SD**	**Absolute difference (2009-2017)**		**% change**
Panel A. Hospitalizations and primary care consultations per 10,000 children and adolescents <20 years of age							
All-causes	435.67	206.20	407.18	214.03	-28.49	p<0.001	-7%
All avoidable causes	141.32	123.57	100.37	110.27	-40.95	p<0.001	-29%
Asthma	21.52	38.40	10.41	29.18	-11.11	p<0.001	-52%
Infectious gastroenteritis	28.61	48.94	18.12	42.5	-7.17	p<0.001	-37%
Pneumonia	68.18	68.50	41.36	54.61	-26.82	p<0.001	-39%
Primary care consultations	6316.97	6192.38	4439.18	4864.42	-1877.79	p<0.001	-30%
Panel B. Municipality characteristics							
GDP per capita (in log scale)	9.01	0.70	9.74	0.68	0.73	p<0.001	8%
Hospital beds per 1,000 people	1.45	1.65	1.25	1.54	-0.2	p<0.001	-14%
Proportion of the population with private plans	0.07	0.10	0.08	0.10	0.01	p<0.001	14%
Proportion of adult population ≥20 years of age	0.63	0.06	0.68	0.06	0.05	p<0.001	8%
Population size							
<5,000	0.23	0.42	0.22	0.42	-0.01	p<0.001	-4%
5,000-9,999	0.23	0.42	0.22	0.41	-0.01	0.02	-4%
10,000-19,999	0.25	0.43	0.24	0.43	-0.01	0.44	-4%
20,000-49,999	0.19	0.39	0.2	0.4	0.01	p<0.001	5%
≥50,000	0.11	0.31	0.12	0.32	0.01	p<0.001	9%

Notes: Hospitalization data were extracted from the Hospital Information System of the public hospitals using ICD-10 groupings indicated in patient discharge records. The GDP per capita was obtained from IBGE. Data on hospital beds and municipality population were obtained from the Ministry of Health. Primary care data were extracted from the SIAB database for 2009-2015, the latest year for which data were available. The proportion of the population with private plans was calculated based on data from the Brazilian Regulatory agency. SD = Standard deviation. P-values are based on OLS regressions to ascertain whether changes in hospitalizations, primary care consultations and municipality characteristics between 2009-2017 were statistically significant.

Table 4.2 Impact of MDP on hospitalization rates per 10,000 children and adolescents <20 years of age in the matched sample, 2009-2017

	(1)	(2)	(3)
All-avoidable causes	-1.95	-1.68	-1.84
	[-5.40,1.50]	[-5.20,1.84]	[-5.34,1.66]
Constant	145.30	145.06	-43.46
	[143.35,147.25]	[143.21,146.91]	[-187.62,100.70]
N (observations)	50,076	50,076	50,076
R^2	0.76	0.77	0.77
Asthma	-1.65	-0.84	-0.87
	[-2.69,-0.61]	[-1.91,0.23]	[-1.94,0.19]
Constant	22.62	22.47	2.47
	[21.98,23.26]	[21.86,23.07]	[-39.15,44.09]
N (observations)	50,076	50,076	50,076
R^2	0.69	0.70	0.70
Infectious gastroenteritis	-0.25	-0.06	-0.11
	[-1.85,1.34]	[-1.72,1.60]	[-1.76,1.55]
Constant	29.88	29.75	6.09
	[29.01,30.74]	[28.93,30.56]	[-43.75,55.94]
N (observations)	50,076	50,076	50,076
R^2	0.73	0.74	0.74
Pneumonia	-0.85	-0.95	-1.02
	[-2.70,1.00]	[-2.85,0.95]	[-2.91,0.87]
Constant	69.66	69.67	-23.97
	[68.55,70.78]	[68.58,70.75]	[-105.19,57.26]
N (observations)	50,076	50,076	50,076
R^2	0.73	0.73	0.73
Controls			
Municipality and year fixed effects	Yes	Yes	Yes
State-by-year fixed effects	No	Yes	Yes
Time-varying municipal controls	No	No	Yes

Notes: The key explanatory variable is a binary indicator that takes value 1 if there is at least one MDP physician serving at the municipality starting from the first year of enrollment in MDP and zero otherwise. Hospitalization data are extracted from the Hospital Information System of the public hospitals using ICD-10 groupings indicated in patient discharge records. Time-varying municipality controls include the municipal GDP per capita (in log scale), hospital beds per 1,000 inhabitants, proportion of the population with private insurance plans, proportion of adult population ≥ 20 years of age and population size. 95%CIs are in brackets. All regressions include CEM weights. In all regressions, standard errors are clustered at the municipality level.

Table 4.3 displays results stratified by location type and Figure 4.2 plots the estimated MDP coefficients. In rural municipalities, the estimated MDP coefficients were -7.43 (95%CI: -13.20,-1.65) for all avoidable causes, -1.68 (95%CI: -3.43,0.07) for asthma, -3.63 (CI95%: -6.65,-0.61) for infectious gastroenteritis, and -0.26 (CI95%: -3.47,2.94) for pneumonia. These results suggest that the MDP led to fewer avoidable hospitalizations in rural municipalities, partly due to infectious gastroenteritis-related cases. However, it did not reduce hospitalizations due to asthma and pneumonia. None of the estimated MDP coefficients were statistically significant for children residing in urban municipalities.

Table 4.3 Impact of MDP on hospitalization rates per 10,000 children and adolescents <20 years of age in the matched sample, by type of residence, 2009-2017

	(1)	(2)
	Rural	Urban
All avoidable causes	-7.43 [-13.20,-1.65]	1.23 [-3.16,5.61]
Constant	82.01 [-101.31,265.33]	-107.81 [-321.63,106.02]
N (observations)	18,243	31,833
R^2	0.79	0.76
Asthma	-1.68 [-3.43,0.07]	-0.42 [-1.77,0.94]
Constant	33.22 [-25.93,92.37]	-10.55 [-68.66,47.57]
N (observations)	18,243	31,833
R^2	0.73	0.68
Infectious gastroenteritis	-3.63 [-6.65,-0.61]	1.78 [-0.16,3.73]
Constant	60.46 [-19.80,140.73]	-23.34 [-92.35,45.66]
N (observations)	18,243	31,833
R^2	0.75	0.73
Pneumonia	-0.26 [-3.47,2.94]	-1.40 [-3.77,0.98]
Constant	-4.57 [-101.51,92.36]	-33.77 [-147.85,80.32]
N (observations)	18,243	31,833
R^2	0.77	0.71

Notes: The key explanatory variable is a binary indicator that takes value 1 if there is at least one MDP physician serving at the municipality starting from the first year of enrollment in MDP and zero otherwise. Hospitalization data are extracted from the Hospital Information System of the public hospitals using ICD-10 groupings indicated in patient discharge records. 95%CIs are in brackets. All regressions include municipality fixed effects and state-time fixed effects. Time-varying municipality controls include the municipal GDP per capita (in log scale), hospital beds per 1,000 inhabitants, proportion of the population with private insurance plans, proportion of adult population ≥ 20 years of age and population size. All regressions include CEM weights. In all regressions, standard errors are clustered at the municipality level.

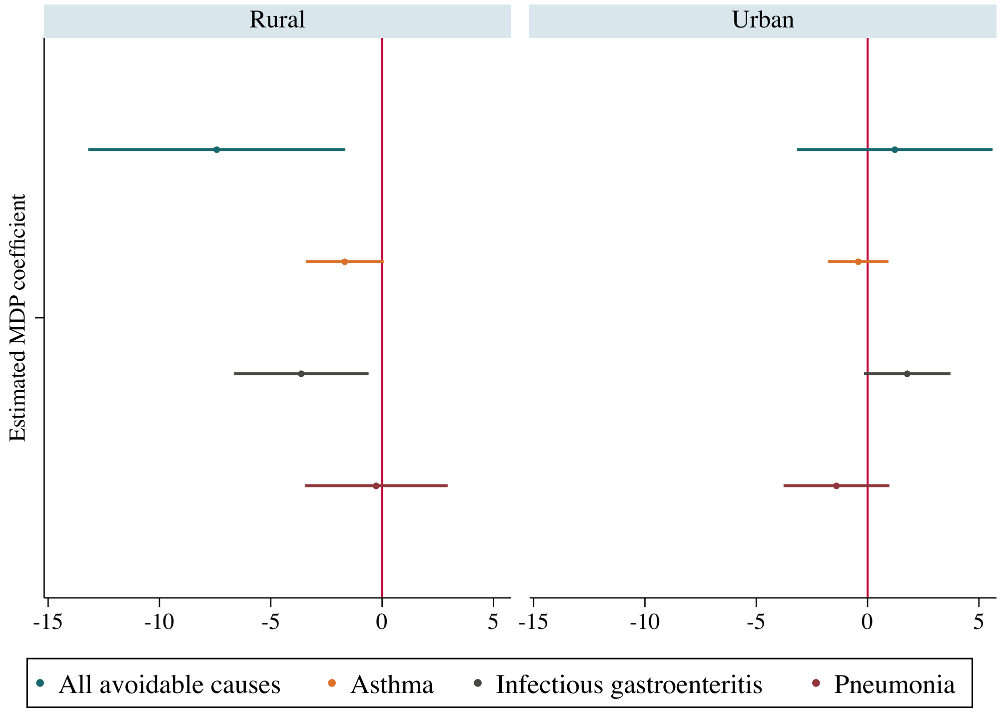

Figure 4.1 Impact of MDP on hospitalization rates per 10,000 children and adolescents <20 years of age in the matched sample, by type of residence, 2009-2017

Notes: The key explanatory variable is a binary indicator that takes value 1 if there is at least one MDP physician serving at the municipality starting from the first year of enrollment in MDP and zero otherwise. Hospitalization data are extracted from the Hospital Information System of the public hospitals using ICD-10 groupings indicated in patient discharge records. 95%CIs are in brackets. All regressions include municipality fixed effects and state-time fixed effects. Time-varying municipality controls include the municipal GDP per capita (in log scale), hospital beds per 1,000 inhabitants, proportion of the population with private insurance plans, proportion of adult population ≥ 20 years of age and population size. All regressions include CEM weights. In all regressions, standard errors are clustered at the municipality level.

Table 4.4 presents the impact of MDP on the number of primary care consultations for children and adolescents under 20 years of age. Our results show that the estimated coefficient on the MDP was 0.07 (CI95%: 0.04,0.10). This finding suggests that, on average, in the MDP municipalities, there was a 7% increase in the number of primary care consultations to children and adolescents. We further show that the increase in the number of primary care consultations was slightly higher in rural municipalities than in urban municipalities, with estimated MDP coefficients of 0.08 (CI95%: 0.03,0.12) and 0.07 (CI95%: 0.03,0.10), respectively.

Table 4.4 Impact of MDP on primary care visits to children and adolescents <20 years of age in the matched sample, 2009-2015

	(1)	(2)	(3)
	Matched sample	Rural	Urban
Primary care visits	0.07 [0.04,0.10]	0.08 [0.03,0.12]	0.07 [0.03,0.10]
Constant	9.79 [8.86,10.71]	9.39 [7.74,11.03]	9.82 [8.66,10.98]
N (observations)	36,562	13,657	22,905
R^2	0.86	0.84	0.87

Notes: The key explanatory variable is a binary indicator that takes value 1 if there is at least one MDP physician serving at the municipality starting from the first year of enrollment in MDP and zero otherwise. Primary care data are extracted from the SIAB database of the MOH. Primary care visits are in logarithmic form. Data is available until the year 2015 (inclusive) for municipalities that reported primary care utilization data for 2009-2015. 95%CIs are in brackets. All regressions include municipality fixed effects and state-time fixed effects. Time-varying municipality controls include the municipal GDP per capita (in log scale), hospital beds per 1,000 inhabitants, proportion of the population with private insurance plans, proportion of adult population ≥ 20 years of age and population size. All regressions include CEM weights. In all regressions, standard errors are clustered at the municipality level.

Table 4.5 presents the estimated MDP coefficients from the event study and Figures 4.3a and 4.3b plot results. We observe that there were declining trends in all avoidable hospitalization rates among children and adolescents under 20 years of age in the years before the MDP was implemented, though none of the estimated coefficients reached statistical significance for years prior to and after the MDP implementation. Our results also suggest that there were no statistically significant trends in the number of primary care visits for children and adolescents under 20 years of age in the years prior to the MDP was implemented. We observe a statistically significant increase in the number of primary care visits starting from the year in which the MDP physicians start working in municipalities. Joint F-tests also revealed that for none of our study outcomes, the estimated coefficients tracking the pre-MDP period were statistically different from one other.

Table 4.5 Pre-trends in hospitalization rates per 10,000 children and adolescents <20 years of age, 2009-2017

	All avoidable causes	Asthma	Infectious gastroenteritis	Pneumonia	Primary care visits*
MDP (Year -4)	3.30	0.60	1.24	1.62	-0.00
	[-1.70,8.30]	[-0.97,2.18]	[-1.05,3.53]	[-1.30,4.54]	[-0.04,0.03]
MDP (Year -3)	1.88	0.75	0.29	0.82	-0.01
	[-1.71,5.47]	[-0.35,1.86]	[-1.38,1.96]	[-1.29,2.93]	[-0.04,0.02]
MDP (Year -2)	-0.13	0.31	0.04	0.13	-0.01
	[-2.49,2.24]	[-0.44,1.05]	[-1.13,1.21]	[-1.27,1.53]	[-0.03,0.01]
MDP (Year 0)	-0.83	-0.26	0.42	-0.90	0.04
	[-3.26,1.60]	[-1.00,0.48]	[-0.73,1.57]	[-2.27,0.48]	[0.02,0.07]
MDP (Year 1)	-1.12	-0.76	-0.18	-0.28	0.12
	[-4.76,2.51]	[-1.78,0.25]	[-1.89,1.54]	[-2.34,1.78]	[0.09,0.16]
MDP (Year 2)	-0.57	-0.99	0.17	0.32	0.24
	[-5.20,4.06]	[-2.36,0.38]	[-2.05,2.39]	[-2.32,2.96]	[0.17,0.31]
MDP (Year 3)	-1.40	-0.90	0.04	-0.84	
	[-7.40,4.59]	[-2.84,1.05]	[-2.79,2.87]	[-3.93,2.26]	
MDP (Year 4)	4.90	0.96	1.83	1.34	
	[-4.44,14.23]	[-2.62,4.53]	[-2.30,5.97]	[-3.18,5.86]	
Constant	-45.63	2.06	5.06	-24.88	9.76
	[-189.75,98.49]	[-39.69,43.82]	[-44.86,54.98]	[-105.92,56.16]	[8.84,10.69]
N	50,076	50,076	50,076	50,076	36,562
R^2	0.77	0.70	0.74	0.73	0.86

Notes: Primary care data are extracted from the SIAB database of the MOH. Primary care visits are in logarithmic form. Data is available until the year 2015 (inclusive) for municipalities that reported primary care utilization data for 2009-2015.

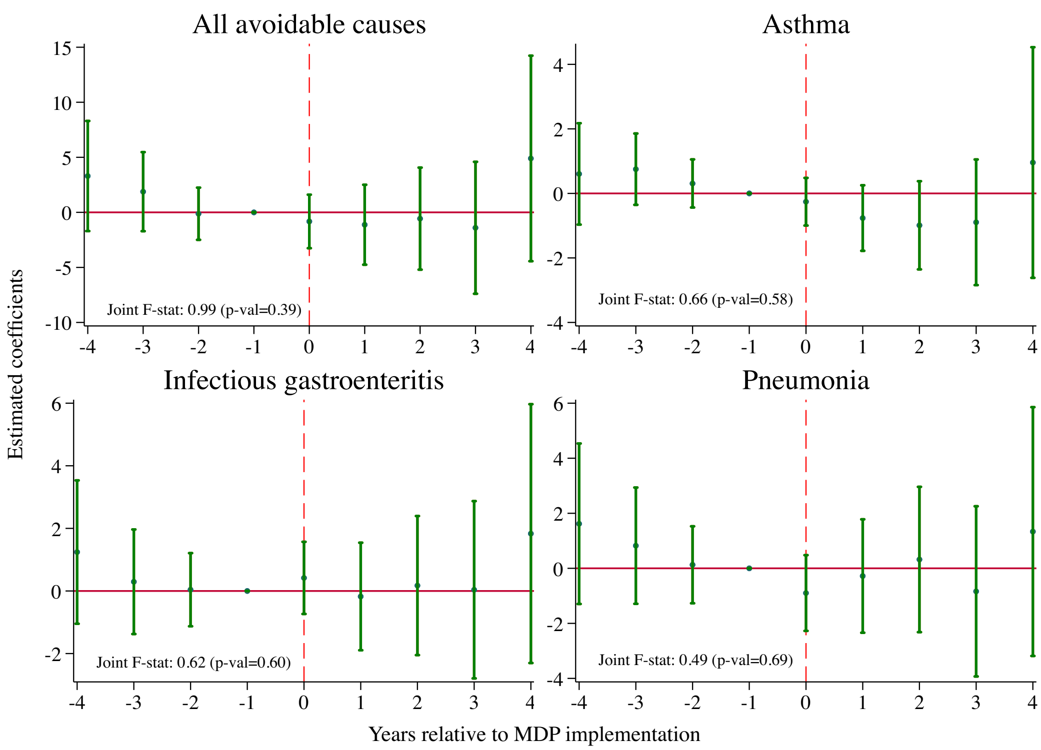

Figure 4.2a Event study for hospitalization rates per 10,000 children and adolescents <20 years of age, 2009-2017

Notes: The estimated coefficients are relative to the year prior to the MDP implementation. The vertical dashed line indicates the start of MDP enrollment. Vertical bars around point estimates represent 95% confidence intervals. Estimated coefficients for periods -4 to 4 should be interpreted as the coefficient on 4 or more years prior to and 4 years since the MDP implementation, respectively.

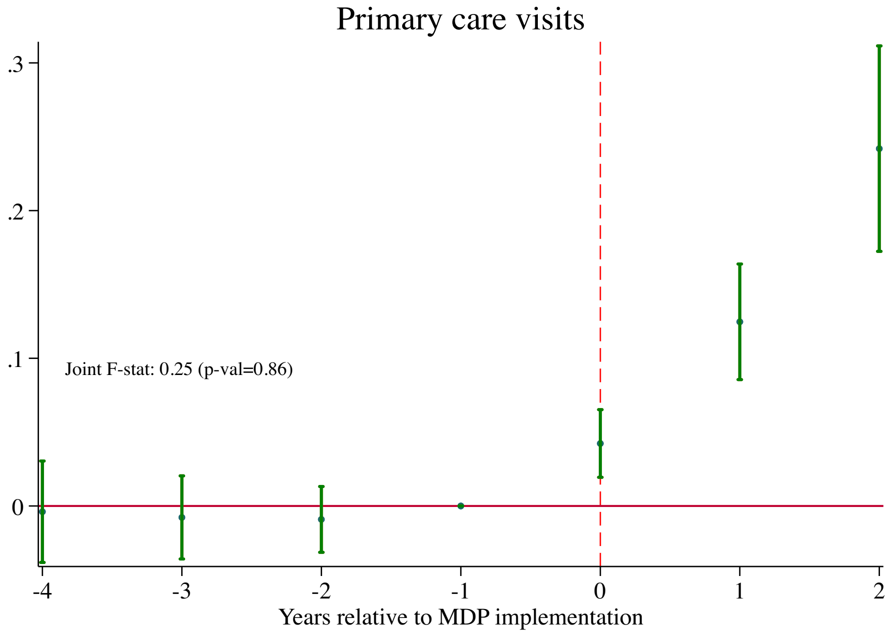

Figure 4.2b Event study for on primary care visits to children and adolescents <20 years of age in the matched sample, 2009-2015

Notes: Primary care data are extracted from the SIAB database of the MOH. Primary care visits are in logarithmic form. Data is available until the year 2015 (inclusive) for municipalities that reported primary care utilization data for 2009-2015. The estimated coefficients are relative to the year prior to the MDP implementation. The vertical dashed line indicates the start of MDP enrollment. Vertical bars around point estimates represent 95% confidence intervals. Estimated coefficients for periods -4 to 4 should be interpreted as the coefficient on 4 or more years prior to and 4 years since the MDP implementation, respectively.

4.5. Discussion

Our study demonstrated that investing in primary care in traditionally underserved settings led to gains in child and adolescent health. We showed that the MDP increased the utilization of primary care and reduced all avoidable hospitalizations in rural municipalities for children and adolescents under 20 years of age, though it did not reduce hospitalizations in urban municipalities. Decomposing our results by health conditions revealed that in rural municipalities, the MDP led to reductions in hospitalizations due to infectious gastroenteritis. However, it did not change hospitalization rates due to asthma or pneumonia. Taken together, our results suggest that the MDP may have contributed to population health in traditionally underserved communities.

There may be several explanations for our findings. The large reductions in avoidable hospitalizations we observed before the launch of the MDP may be attributable to a wide array of public health initiatives implemented since the 1980s. Over the last three decades, more than fifty maternal and child health initiatives have been created by the national and subnational governments (Barros *et al.* 2010; Victora *et al.* 2011; Paim *et al.* 2011). These efforts were complemented by other public health initiatives to improve nutrition, education and health promotion, as well as the economic well-being of households living in poverty. Additionally, the National Immunization Program (NIP) provides near-universal coverage for 19 vaccines (Castro *et al.* 2019). Recent vaccination programs (e.g. the introduction of a rotavirus vaccine in 2006, and a 10-valent pneumococcal conjugate vaccine in 2010) have been associated with reductions in hospitalizations and mortality associated with avoidable conditions, including diarrhea and pneumonia, among young children (Do Carmo *et al.* 2011; Afonso *et al.* 2013; Sartori *et al.* 2017; Schuck-Paim *et al.* 2019).

Increases in the number of primary care physicians alone may not have been sufficient to address the existing weakness within the organization of the FHS for addressing child and adolescent health. For instance, two recent studies suggested that the FHS does not clear strategy to address health challenges facing adolescents (da Costa *et al.* 2012; Yamaguchi *et al.* 2014), even though this group has been shown to be at risk (Schaefer *et al.* 2018). None of the design features of the MDP directly tackles challenges in access to child and adolescent health services.

In our analysis, we were unable to distinguish the case severity of each hospitalization, identify patients with comorbidities, and identify re-admissions due to the lack of the ICD-10 codes for each patient and health condition. However, changes in the case severity may be particularly important for chronic conditions, where primary care is suggested to be more crucial for reducing hospitalizations due to the acute complications or re-admissions of an already diagnosed condition (Mendoça *et al.* 2012). For instance, the ICD-10 groupings we used for asthma aggregates all types of asthma-related hospitalizations (e.g. nonallergic, mixed and unspecified asthma, and acute severe asthma), limiting our ability to ascertain the differential effects of the MDP by the severity of this condition. Future studies can examine whether the MDP led to changes in the case severity, comorbidities and re-admission rates for primary-care sensitive conditions.

Our work relates to three strands of literature. First, we add to the body of literature that examines the contribution of primary care on child and adolescent health. Our findings are in line with previous research focusing on the MDP. Carillo and Feres (2019) showed that the MDP led to a 4.3% increase in physician visits but did not reduce infant mortality. Using a sample of 2,940 municipalities, Mattos and Mazetto (2019) similarly reported that the Program led to increases in primary care consultations, though it fell short of reducing hospitalization rates among children under 5 years of age between the period from 2010 to 2015.

Second, we extend the body of research on strengthening the primary care orientation of health systems on hospitalizations for conditions amenable to timely and appropriate provision of outpatient services. In Brazil, most studies conclude that stronger primary care orientation is associated with reductions in adult hospitalizations due to primary care sensitive conditions (Macinko *et al.* 2010; Macinko *et al.* 2011; Da Silva and Powell-Jackson 2017; Santos *et al.* 2017), though we know relatively little about the differential impact of FHS by age groups. Fontes and colleagues (2018) showed that the MDP led to reductions in hospitalizations due to primary care conditions between 2010 and 2015, though the study did not disaggregate results by age groups or health conditions. Most recently, Maffioli *et al.* 2019 generated causal evidence in line with finding from Fontes *et al.* (2018) and indicated that the observed declines in avoidable hospitalizations were partly due to reductions in the burden of infectious gastroenteritis. However, this study did not provide age-specific results for the conditions we examined.

Third, our study relates to the literature on the role of primary care programs in reducing rural-urban disparities. Consistent with this literature, we showed that increased investment in primary care in underserved communities in Brazil contributed to the reduction of urban-rural health disparities in hospitalizations. Aquino and colleagues (2009) found that the FHS led to declines in infant mortality, with municipalities with lower levels of development benefiting more from the program. Rocha and Soares (2010) found similar reductions in infant mortality and showed that the impact of the FHS expansion was more pronounced among municipalities located in the poorest regions, including in the North and Northeast. In a 2017 study, Hone and colleagues showed that the expansion of FHS led to reductions in racial inequities in mortality rates due to conditions sensitive to primary care (Hone *et al* 2017a). Our results are also in line with findings from studies that document the impact of strengthening primary care provision in developing countries on narrowing geographic and socioeconomic health disparities (Vapattanawong *et al.* 2007; Memirie *et al.* 2016).

Our results pave the way for future studies that can shed light on the drivers of the effectiveness of primary care programs in urban and rural communities. We showed that over the study period, hospitalization rates due to asthma, infectious gastroenteritis, and pneumonia remained higher for children and adolescents residing in rural municipalities than their counterparts from urban municipalities. This finding suggests that there may be broader socioeconomic factors that contribute to the urban-rural discrepancies in the utilization of hospital services among children and adolescents.

Our study has many strengths. In this study, we provided an in-depth analysis of the impact of MDP on hospitalizations for children and adolescents under 20 years of age. In addition to reporting main treatment effects, we disaggregated our results by disease conditions considered to be primary care sensitive, reported heterogeneous treatment effects, and explored potential mechanisms that can explain our results. Our estimates are based on the HIS, which provides all hospitalizations financed by the UHS for children and adolescents under 20 years of age for a period of 8 years. To address potential endogeneity concerns, we employed a causal study design that combined coarsened exact matching and difference-in-difference methods. Our post-matching study sample represented almost all municipalities, which was an important limitation of many previous studies (Carillo and Feres 2017; Fontes *et al.* 2018; Mattos and Mazetto 2019). Our data allowed us to derive event study estimates to parse out the yearly effects of the program. Our substantive results remained robust to several sensitivity checks.

Our study has some limitations. While we observed increases in the number of primary care consultations, we were unable to ascertain whether a physician was present in these consultations. We were also unable to examine whether the MDP led to improvements in the comprehensiveness, continuity, and/or coordination of care. Improvements in these areas might be particularly beneficial for younger individuals. Our main explanatory variable was a binary measure which tracked the presence of MDP physicians across communities over time. While this approach allowed us to exploit the geographic variation in the uptake of the program, it did not take into account the number of MDP physicians that were working in each municipality. Therefore, it is plausible that our approach may not have accounted for the main mechanisms through which cause-specific hospitalizations were impacted by the MDP. We used CEM to address potential endogeneity concerns arising from the non-random enrollment in MDP. While we carefully selected municipal-level covariates for CEM using our contextual knowledge of the prioritization criteria used by the MOH, statistically significant differences in the empirical distribution of the municipal GDP per capita, hospital beds per 1,000 inhabitants and the proportion of the population above the age of 20 and above remained between the MDP and non-MDP municipalities. While we controlled for these time-varying municipal-level characteristics in our regressions, we cannot rule out any remaining bias in our estimates. Our data did not allow us to distinguish between municipalities that did not have any MDP physicians, because their applications were denied and municipalities that did not apply to join the program. Olivera *et al.* (2016) noted that the MOH rarely denied applications, we cannot rule out any potential bias in our estimates if those with denied applications differed systematically from municipalities that did not submit applications. We observed declining trends in avoidable hospitalizations prior to the implementation of the MDP. While our event study estimates suggested that there were no statistically significant differences in the estimated coefficients in the pre-MDP period, we are unable to rule out bias in our estimates. Our DID estimates rely on the assumption that in the absence of the program, hospitalization rates between MDP and non-MDP municipalities would have evolved similarly over time. While we performed several sensitivity checks to examine evidence to support this assumption, we cannot rule out any potential violations as discussed in earlier works (Borusyak and Jaravel 2017; Goodman-Bacon 2018; Roth 2018; Callaway and Sant'Anna 2019; Bilinski and Hatfield 2019). We may have underestimated asthma-related hospitalizations due to the difficulties around correctly diagnosing this condition among children under 5 years of age. However, we do not expect the MDP to change patterns of asthma misdiagnosis in secondary and tertiary hospitals. Our study focused on cause-specific hospitalizations based on data from the HIS using ICD-10 code groupings. While several earlier studies indicated that the HIS offers a highly reliable source of information (Mathias *et al.* 1998; Bittencourt *et al.* 2006; Bittencourt *et al.* 2008; Sgambatti *et al.* 2015), we cannot rule out any inconsistencies in the coding of cause-specific hospitalizations.

4.6. Conclusion

Our study provides new causal evidence that strengthening the primary care orientation of the health system may lead to gains in child and adolescent health. While we did not find that the MDP led to measurable reductions in all health conditions we studied, we also showed that it contributed to the narrowing of disparities in avoidable hospitalizations between urban and rural communities. Lessons from the Brazilian experience in the infusion of substantial resources to strengthening primary care provision in underserved communities can inform future efforts to improve child and adolescent health.

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Appendix

Table A4.1 Overview of ICD-10 groupings used in the analysis

Data	Variables
Vaccine-preventable diseases	Tuberculous meningitis (ICD10-A17), Military tuberculosis (ICD10-A19), tetanus (ICD10- A33-A35), diphtheria (ICD10- A36), whooping cough (ICD10- A37), yellow fever (ICD10- A95), measles (ICD10- B05), rubella (ICD10- B06), acute hepatitis B (ICD10- B16), mumps (ICD10- B26), haemophilus meningitis (ICD10- G00)
Infectious gastroenteritis	Cholera (ICD10-A00), typhoid and paratyphoid fevers (ICD10-A01), shigellosis (ICD10- A-03), amoebiasis (ICD10-A06), diarrhea and presumed infectious gastroenteritis (ICD10-A09)
Malnutrition	Anemia (ICD10-D50), Malnutrition (ICD10-E40-E46), vitamin A deficiency (ICD10-E50), other vitamin deficiencies (ICD10- E51-E56), sequelae of malnutrition and other nutritional deficiencies (ICD10- E64), dehydration (E86)
Cardiovascular conditions	Cerebrovascular diseases(ICD10-I63, I64, I65-69, G45), heart failure (ICD10-I50), hypertension (ICD10- I10), other forms of heart diseases including angina and acute myocardial infarction (ICD10 - I20, I23-I25, ICD10- I21-I22)
Other preventable conditions	Congenital syphilis (ICD10-A50), syphilis (ICD10- A51-A53), pulmonary tuberculosis (ICD10-A15.0-A15.3, A16.0-A16.3), other respiratory tuberculosis (ICD10-A15.4-A15.9, A16.4-A16.9), other tuberculosis(ICD10-A18), malaria (B50-B54), diabetes mellitus (ICD10-E10-E14), epilepsy (ICD10-G40-41), otitis media and other disorders of the middle ear and mastoid apophysis (ICD10-H65-H75), acute rheumatic fever (ICD10- I00-02), other hypertensive diseases (ICD10-I11-I15), other acute upper airway infections (ICD10-J00-J01, J05-J06), acute pharyngitis and acute tonsillitis(ICD10-J02-J03), pneumonia (ICD10- J12-J18), acute bronchitis and acute bronchiolitis (ICD10- J20-J21), bronchitis, emphysema and other chronic obstructive pulmonary diseases (ICD10-J40-44), asthma (ICD10-J45-J46), bronchiectasis (ICD10-J47), cystitis(ICD10-N30), salpingitis and oophoritis (ICD10-N70), inflammatory cervical disease (ICD10-N72), other inflammatory diseases of the female pelvic organs (ICD10-N71, N73, N77), skin and subcutaneous tissue infections (ICD10-L00-L08)

Notes: Hospitalizations due to conditions sensitive to primary care interventions are based on the list of 19 groups of conditions with 74 diagnoses categories classified in accordance with ICD-10 groupings published by the Brazilian Ministry of Health in Ministerial Ordinance No. 221 on April 17, 2008, as well as conditions indicated as avoidable in the recent study conducted by Fontes and colleagues (2018).

Table A4.2 Sample primary care actions to prevent the need for hospitalization by health condition

Condition	*Primary care action*
Asthma	Monitor inhaler and medication use Reduce the level of exposure to common risk factors (e.g. tobacco smoke, air pollution) Smoking cessation programs for parents Asthma education and nutrition counseling
Diarrhea	Rehydration: Oral rehydration salts (ORS) solution Promotion of exclusive breastfeeding Nutrition counseling (e.g. zinc supplements, food preparation practices, feeding during and after a diarrheal episode) Health education on safe drinking water, sanitation, and personal hygiene
Pneumonia	Vaccination (e.g. Haemophilus influenzae type b, valent pneumococcal conjugate vaccine [PCV], measles and whooping cough [pertussis]) Promotion of exclusive breastfeeding Prescription of antibiotics by trained health personnel Nutrition counseling Health education on environmental factors (e.g. indoor air pollution), personal hygiene

Notes: Adapted from WHO 2019a; WHO 2019b; WHO 2019c

Table A4.3 Descriptive statistics in the pre- and post-matched sample, 2009-2017

	Pre-matched sample				Post-matched sample	
	non-MDP		MDP		non-MDP	
Panel A. Hospitalizations per 10,000 children	Mean	SD	Mean	SD	Mean	SD
All-causes	423.31	204.94	414.77	206.04	429.58	205.16
All avoidable causes	121.68	116.01	106.43	110.79	126.16	117.87
Asthma	16.16	33.66	12.12	28.14	17.52	34.95
Infectious gastroenteritis	25.77	49.18	21.44	44.19	27.21	50.54
Pneumonia	54.83	61.96	44.12	56.85	56.55	61.87
Panel B. Municipality characteristics						
GDP per capita (in log scale)	9.35	0.75	9.59	0.69	9.31	0.76
Hospital beds per 1,000 inhabitants	1.37	1.67	1.31	1.46	1.43	1.52
Proportion of the population with private plans	0.08	0.11	0.08	0.11	0.08	0.11
Proportion of adult population ≥20 years of age	0.66	0.06	0.67	0.06	0.64	0.07
Population size						
<5,000	0.26	0.44	0.16	0.36	0.16	0.37
5,000-9,999	0.23	0.42	0.20	0.40	0.20	0.40
10,000-19,999	0.24	0.43	0.26	0.44	0.26	0.44
20,000-49,999	0.17	0.38	0.23	0.42	0.22	0.41
≥50,000	0.09	0.29	0.15	0.36	0.14	0.35
Number of observations						
Multivariate L_1 distance				0.29		0.21

Notes: Hospitalization data are extracted from the Hospital Information System of the public hospitals using ICD-10 groupings indicated in patient discharge records. GDP per capita is obtained from IBGE. Data on hospital beds and municipality population characteristics are obtained from the Ministry of Health. Proportion of the population with private plans was calculated based on data from the Brazilian Regulatory Agency. SD = Standard deviation.

Subgroup Analysis – Baseline FHS coverage

As an additional subgroup analysis, the impact of the MDP by baseline FHS coverage was assessed. For this analysis, we merged two publicly available datasets. First, we obtained the number of FHS teams in each municipality from the MOH for the month of June in 2013 (i.e. a month before the first MDP physicians arrived in Brazil). We linked this data with the number of inhabitants in each municipality from the IBGE website.

We divided municipalities into four categories based on their baseline FHS coverage. We calculated the FHS coverage as the number of FHS teams in each municipality divided by population size, multiplied by 3,500 as per the MOH guidelines. We expected that municipalities with the lowest levels of FHS coverage at baseline would benefit more from the MDP than higher coverage areas. Table A4.4 presents results and Figure A4.1 displays the estimated MDP coefficients for visual ease. We find that in municipalities with less than 25% FHS coverage at baseline, the estimated MDP coefficients were -7.51 (CI95%: -14.80,-0.22) for avoidable causes, -0.98(CI95%:-2.64,0.69) for asthma, -1.12 (CI95%: -3.70,1.46) for infectious gastroenteritis and -6.52 (CI95%: -10.94,-2.09) for pneumonia. None of the estimated MDP coefficients were statistically significant for municipalities with higher FHS coverage in 2012. These results suggest that, in congruence with our expectations, the MDP was most beneficial in communities where the FHS needs were the greatest at baseline. In these municipalities, the MDP led to reductions in avoidable hospitalizations, partly due to pneumonia.

Table A4.4 Impact of the MDP on avoidable hospitalizations, by FHS coverage at baseline, 2009-2017

	FHS Q(1)	FHS Q(2)	FHS Q(3)	FHS Q(4)
All avoidable causes	-7.51	0.04	1.53	-1.95
	[-14.80,-0.22]	[-8.04,8.11]	[-6.47,9.54]	[-6.34,2.44]
Constant	355.65	-286.65	-109.23	-58.64
	[-9.01,720.32]	[-851.75,278.46]	[-512.88,294.42]	[-234.95,117.66]
N (observations)	3402	3618	6201	36855
R^2	0.77	0.81	0.80	0.77
Asthma	-0.98	-0.47	-0.45	-1.11
	[-2.64,0.69]	[-3.31,2.37]	[-2.81,1.91]	[-2.48,0.25]
Constant	85.53	-56.12	-57.91	-0.58
	[5.83,165.24]	[-182.05,69.82]	[-241.22,125.40]	[-46.30,45.14]
N (observations)	3402	3618	6201	36855
R^2	0.72	0.78	0.75	0.69
Infectious gastroenteritis	-1.12	0.27	0.27	0.12
	[-3.70,1.46]	[-3.25,3.79]	[-3.77,4.30]	[-1.98,2.21]
Constant	105.49	-11.93	72.84	-5.78
	[-27.24,238.22]	[-309.31,285.45]	[-84.63,230.31]	[-66.77,55.21]
N (observations)	3402	3618	6201	36855
R^2	0.73	0.78	0.78	0.73
Pneumonia	-6.52	-1.12	0.87	-0.81
	[-10.94,-2.09]	[-5.67,3.44]	[-3.42,5.16]	[-3.16,1.54]
Constant	139.60	-131.40	-32.60	-23.01
	[-68.59,347.79]	[-436.24,173.44]	[-243.01,177.81]	[-123.86,77.85]
N (observations)	3402	3618	6201	36855
R^2	0.73	0.77	0.74	0.74

Notes: We divide municipalities into four categories based on their FHS coverage in the month of June in 2013. The FHS coverage is calculated as the number of FHS teams in each municipality divided by municipality population and multiplied by 3,500. Quartile 1 presents the lowest FHS coverage (0%-24.9%) and quartile 4 corresponds to the highest level of FHS coverage (75%-100%). The key explanatory variable is a binary indicator that takes value 1 if there is at least one MDP physician serving at the municipality starting from the first year of enrollment in MDP and zero otherwise. Hospitalization data are extracted from the Hospital Information System of the public hospitals using ICD-10 groupings indicated in patient discharge records. All regressions include municipality fixed effects and state-time fixed effects. Time-varying municipality controls include the municipal GDP per capita (in log scale), hospital beds per 1,000 inhabitants, proportion of the population with private insurance plans, proportion of adult population ≥ 20 years of age and population size. 95%CIs are in brackets. All regressions include CEM weights. In all regressions, standard errors are clustered at the municipality level.

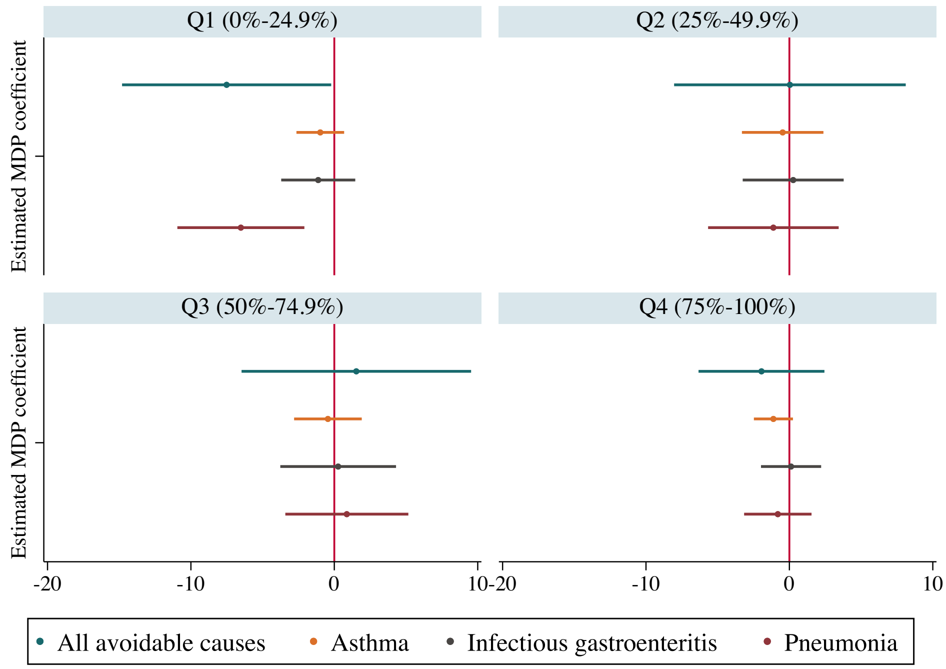

Figure A4.1 Impact of the MDP on avoidable hospitalizations, by FHS coverage at baseline (2013), 2009-2017

Notes: We divide municipalities into four categories based on their FHS coverage in the month of June in 2013. The FHS coverage is calculated as the number of FHS teams in each municipality divided by municipality population and multiplied by 3,500. Quartile 1 present the lowest FHS coverage (0%-24.9%) and quartile 4 corresponds to the highest level of FHS coverage (75%-100%). The key explanatory variable is a binary indicator that takes value 1 if there is at least one MDP physician serving at the municipality starting from the first year of enrollment in MDP and zero otherwise. Hospitalization data are extracted from the Hospital Information System of the public hospitals using ICD-10 groupings indicated in patient discharge records. All regressions include municipality fixed effects and state-time fixed effects. Time-varying municipality controls include municipal GDP per capita (in log scale), hospital beds per 1,000 inhabitants, proportion of the population with private insurance plans, proportion of adult population ≥ 20 years of age and population size. All regressions include CEM weights. In all regressions, standard errors are clustered at the municipality level.

Subgroup Analysis – MDP vulnerable community designation

As an additional subgroup analysis, we examined the impact of the MDP by MDP vulnerability designation status. For this analysis, we grouped municipalities into two categories. A municipality was classified ever-targeted if it was ever designated vulnerability status in the MDP in the study period and non-target otherwise.

Table A4.5 presents results. We find in ever-targeted municipalities, the estimated MDP coefficients were -2.10 (CI95%: -6.61,2.41) for all avoidable causes, -1.18(CI95%: -2.65,0.29) for asthma, -0.54 (CI95%: -2.89,1.81) for infectious gastroenteritis and 0.58 (CI95%: -1.60,2.77) for pneumonia. These results suggest the presence of MDP physicians was inversely associated with avoidable hospitalizations, except pneumonia, in ever-targeted municipalities. However, none of the estimate MDP coefficients reached statistical significance. In non-target municipalities, the none of the estimated MDP coefficients were statistically significant except pneumonia. For pneumonia, we show that the estimated coefficient on MDP was -4.21 (CI95%: -7.93,-0.49), suggesting that the MDP led to fewer hospitalizations due to pneumonia in non-target municipalities.

Table A4.5 Impact of the MDP on avoidable hospitalizations, by MDP target community status, 2009-2017

	(1)	(2)
	Ever-targeted	Non-target
All avoidable causes	-2.10 [-6.61,2.41]	-1.98 [-7.71,3.75]
Constant	-53.59 [-217.25,110.08]	-12.42 [-275.87,251.03]
N (observations)	33498	16578
R^2	0.79	0.72
Asthma	-1.18[-2.65,0.29]	-0.47[-1.92,0.98]
Constant	-8.31[-71.69,55.07]	28.11[-7.49,63.72]
N (observations)	33498	16578
R^2	0.71	0.63
Infectious gastroenteritis	-0.54 [-2.89,1.81]	0.56 [-1.42,2.54]
Constant	-1.41[-73.00,70.19]	20.76 [-37.97,79.49]
N (observations)	33498	16578
R^2	0.75	0.66
Pneumonia	0.58 [-1.60,2.77]	-4.21 [-7.93,-0.49]
Constant	-34.04 [-111.35,43.28]	-4.42 [-159.65,150.80]
N (observations)	33498	16578
R^2	0.75	0.69

Notes: We group municipalities into two categories based on their vulnerability designation status in MDP. More information on vulnerability designations are in Chapter 2. The key explanatory variable is a binary indicator that takes value 1 if there is at least one MDP physician serving at the municipality starting from the first year of enrollment in MDP and zero otherwise. Hospitalization data are extracted from the Hospital Information System of the public hospitals using ICD-10 groupings indicated in patient discharge records. All regressions include municipality fixed effects and state-time fixed effects. Time-varying municipality controls include municipal GDP per capita (in log scale), hospital beds per 1,000 inhabitants, proportion of the population with private insurance plans, proportion of adult population ≥ 20 years of age and population size. All regressions include CEM weights. In all regressions, standard errors are clustered at the municipality level.

ADDITIONAL SENSITIVITY CHECKS

In this section, we present results from additional sensitivity checks.

Sensitivity check I

The DID method relies on the assumption that in the absence of the program, trends in the key hospitalization outcomes would have evolved similarly over time (e.g. common trends assumption). A violation of this assumption will lead to bias in our estimates. Even though there are no statistical tests to confirm the common trends assumption, we perform several checks. First, we visually examine the trends in the hospitalization rates and the number of primary care consultations per 10,000 children and adolescents across MDP and non-MDP municipalities. In Figures A4.2 and A4.3, we observe similar trends in all study outcomes between the MDP and non-MDP municipalities in the years prior to the launch of the MDP in 2013. For the year 2015, the stark decline in the number of primary care consultations is attributed to the discontinuation of the data reporting in the SIAB database this year in the month of July.

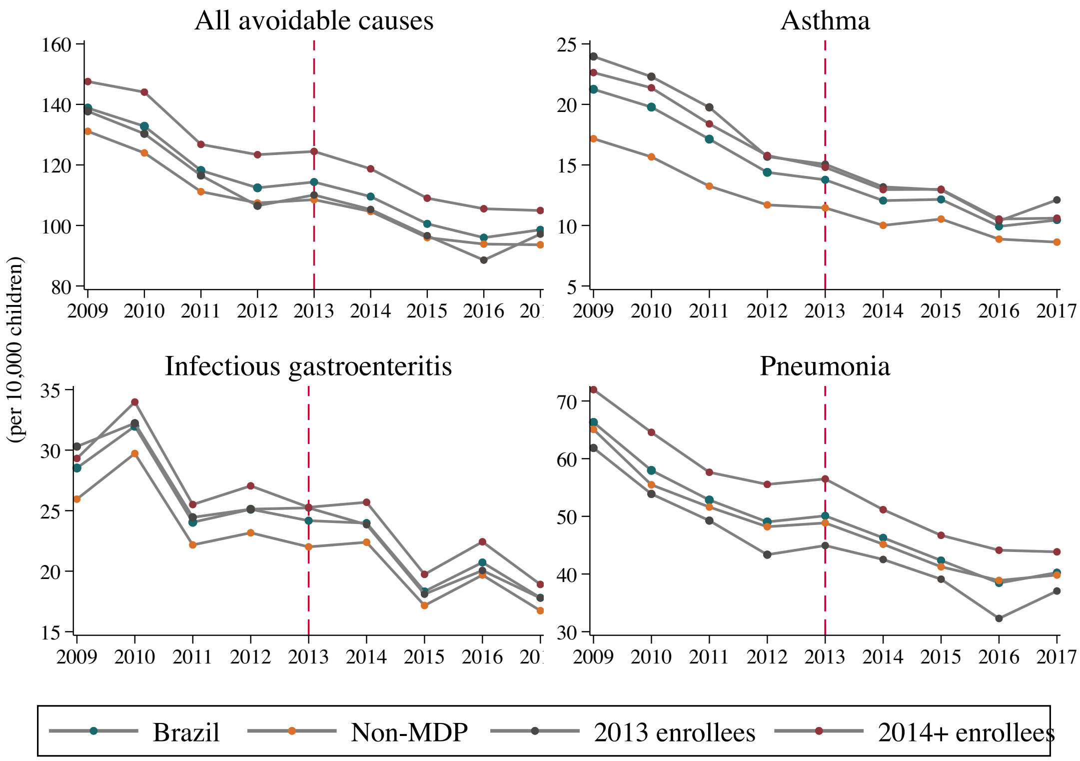

Figure A4.2 Trends in hospitalization rates per 10,000 children and adolescents<20 years of age in the matched sample, by MDP enrollment year, 2009-2017

Notes: We combined municipalities that were enrolled in the MDP between 2015-2017 for visual ease, because only a few municipalities that had not been previously enrolled in the program joined it after 2015. Hospitalization data are extracted from the Hospital Information System of the public hospitals using ICD-10 groupings indicated in patient discharge records. The dotted line in 2013 marks the year MDP was introduced in Brazil.

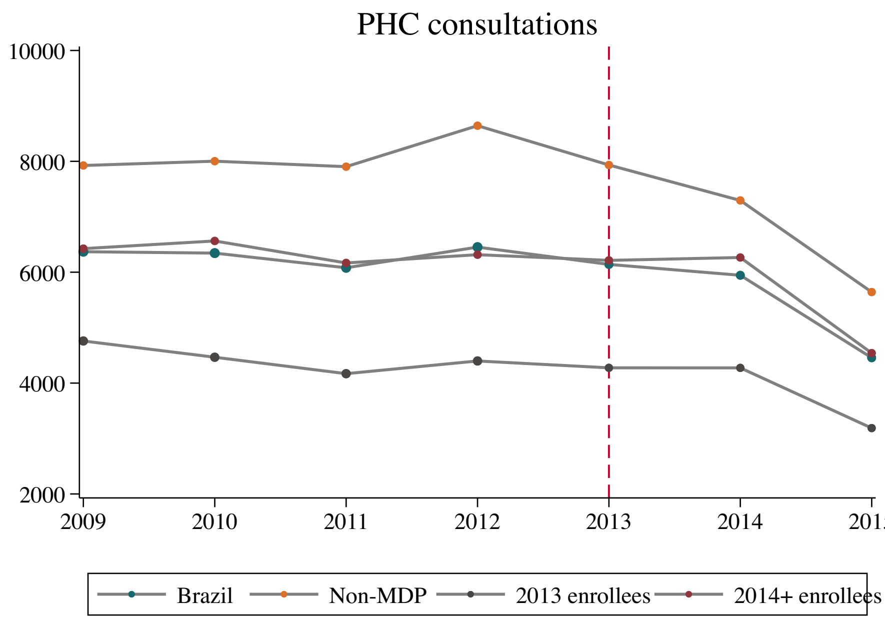

Figure A4.3 Trends in the number of primary care consultations per 10,000 children and adolescents <20 years of age in the matched sample, by MDP enrollment year, 2009-2017

Notes: We combined municipalities that were enrolled in the MDP between 2014-2017 for visual ease, because only a few municipalities that had not been previously enrolled in the program joined it after 2015. Primary care data are extracted from the SIAB database of the MOH for 2009-2015, the latest year for which data is available. The dotted line in 2013 marks the year MDP was introduced in Brazil.

Sensitivity check II

Next, we perform a test to investigate whether there were statistically significant differences in hospitalization rates between the MDP and non-MDP municipalities prior to the national roll out of the program in 2013. For this analysis, we re-estimate our main model with an additional interaction between a binary indicator for whether a municipality was ever enrolled in the MDP in the study period and a linear time trend using data from 2009-2012. As shown in Table A4.6, none of the estimated coefficients are statistically different from zero.

Table A4.6 Test of equality in hospitalization rates between MDP and non-MDP municipalities prior to the program introduction

	All avoidable causes	Asthma	Infectious gastroenteritis	Pneumonia
Interaction term (time and ever enrolled in MDP)	-1.43	0.55	0.31	-1.66
	[-8.11,5.25]	[-0.86,1.96]	[-1.55,2.16]	[-6.81,3.48]
Constant	-125.04	-14.64	-34.19	-68.04
	[-363.85,113.78]	[-99.85,70.57]	[-137.95,69.56]	[-207.51,71.42]
N (observations)	22,256	22,256	22,256	22,256
R^2	0.88	0.86	0.86	0.85
Controls				
Municipality and year fixed effects	Yes	Yes	Yes	Yes
State-by-year fixed effects	Yes	Yes	Yes	Yes
Time varying municipal controls	Yes	Yes	Yes	Yes

Notes: Hospitalization data are extracted from the Hospital Information System of the public hospitals using ICD-10 groupings indicated in patient discharge records. 95%CIs are in brackets. All regressions include municipality fixed effects and state-time fixed effects. Time-varying municipality controls include municipal GDP per capita (in log scale), hospital beds per 1,000 inhabitants, proportion of the population with private insurance plans, proportion of adult population ≥ 20 years of age and population size. All regressions include CEM weights. In all regressions, standard errors are clustered at the municipality level.

Sensitivity check III

Next, we re-estimate our principle regression using a subset of municipalities that were continuously enrolled in the MDP between the period 2013-2017, with no discontinuation in the participation in the program after the initial year of enrollment. Similar to our main results, none of the estimated MDP coefficients presented in Table A4.7 reach statistical significance. The estimated MDP coefficients for avoidable causes, asthma and pneumonia are negative, indicating an inverse relationship between the MDP and hospitalization rates.

Table A4.7 Impact of MDP on childhood hospitalizations using a subset of municipalities that were continuously enrolled in the program

	(1)	(2)	(3)
All avoidable causes	0.84 [-2.35,4.02]	0.02 [-3.44,3.47]	-0.25 [-3.70,3.19]
Constant	147.84 [145.63,150.05]	147.56 [145.47,149.65]	-33.22 [-197.39,130.96]
N (observations)	37,476	37,476	37,476
R^2	0.77	0.78	0.78
Asthma	-0.15 [-1.17,0.87]	-0.04 [-1.19,1.11]	-0.10 [-1.25,1.05]
Constant	23.60 [22.88,24.32]	23.41 [22.72,24.09]	1.42 [-45.64,48.49]
N (observations)	37,476	37,476	37,476
R^2	0.71	0.72	0.72
Infectious gastroenteritis	1.31[-0.20,2.83]	0.62 [-1.05,2.29]	0.56 [-1.11,2.23]
Constant	30.56 [29.59,31.54]	30.40 [29.48,31.32]	14.08 [-38.33,66.49]
N (observations)	37,476	37,476	37,476
R^2	0.73	0.74	0.74
Pneumonia	-0.44 [-2.23,1.35]	-0.58 [-2.45,1.29]	-0.69 [-2.56,1.18]
Constant	70.42 [69.17,71.68]	70.44 [69.22,71.66]	-27.13 [-127.51,73.25]
N (observations)	37,476	37,476	37,476
R^2	0.74	0.75	0.75
Controls			
Municipality and year fixed effects	Yes	Yes	Yes
State-by-year fixed effects	No	Yes	Yes
Time-varying municipal controls	No	No	Yes

Notes: The key explanatory variable is a binary indicator that takes value 1 if there is at least one MDP physician serving at the municipality starting from the first year of enrollment in MDP and zero otherwise. Hospitalization data are extracted from the Hospital Information System of the public hospitals using ICD-10 groupings indicated in patient discharge records. 95%CIs are in brackets. All regressions include municipality fixed effects and state-time fixed effects. Time-varying municipality controls include the municipal GDP per capita (in log scale), hospital beds per 1,000 inhabitants, proportion of the population with private insurance plans, proportion of adult population ≥ 20 years of age and population size. All regressions include CEM weights. In all regressions, standard errors are clustered at the municipality level.

Sensitivity check IV

Next, we re-estimate our principle regression using hospitalizations due to non-avoidable conditions as our outcome variable. We calculate the burden of non-avoidable causes by subtracting the number of hospitalizations due to all avoidable conditions from the number of all-cause hospitalizations. We expect that the MDP did not impact hospitalization rates due to non-avoidable causes, because these conditions are not sensitive to the provision of timely and appropriate primary care services. As shown in Table A4.8, the estimated MDP coefficient is not statistically different from zero, as expected. This finding increases our confidence that our findings are not spurious.

Table A4.8 The impact of MDP on hospitalizations due to non-avoidable causes among children and adolescents <20 years of age in the matched sample, 2009-2017

	(1)	(2)	(3)
Non-avoidable causes	0.06	-2.35	-2.42
	[-4.37,4.49]	[-6.71,2.01]	[-6.73,1.89]
Constant	297.91	297.68	-311.89
	[295.73,300.08]	[295.61,299.75]	[-661.97,38.19]
N (observations)	50,076	50,076	50,076
R^2	0.68	0.70	0.70
Controls			
Municipality and year fixed effects	Yes	Yes	Yes
State-by-year fixed effects	No	Yes	Yes
Time varying municipal controls	No	No	Yes

Notes: The key explanatory variable is a binary indicator that takes value 1 if there is at least one MDP physician serving at the municipality starting from the first year of enrollment in MDP and zero otherwise. Hospitalization data are extracted from the Hospital Information System of the public hospitals using ICD-10 groupings indicated in patient discharge records. 95%CIs are in brackets. All regressions include municipality fixed effects and state-time fixed effects. Time-varying municipality controls include municipal GDP per capita (in log scale), hospital beds per 1,000 inhabitants, proportion of the population with private insurance plans, proportion of adult population ≥ 20 years of age and population size. All regressions include CEM weights. In all regressions, standard errors are clustered at the municipality level.

Sensitivity check V

We re-estimate our principle regression by replacing the 2015 age structure values with the growth rate of the children and adolescents under 20 years of age between 2014-2015 to test whether our results are robust to the scaling of hospitalization rates. As shown in Table A4.9, the substantive results remain robust, and the magnitude of the estimated MDP coefficients are very similar to those presented in Table 4.3.

Table A4.9 Impact of MDP on hospitalization rates per 10,000 children and adolescents <20 years of age in the matched sample, 2009-2017, using a different age structure assumption

	(1)	(2)	(3)
All avoidable causes	-1.89 [-5.36,1.59]	-1.67 [-5.22,1.87]	-1.83 [-5.36,1.69]
Constant	145.29 [143.34,147.25]	145.06 [143.20,146.91]	-90.29 [-220.97,40.39]
N (observations)	50,076	50,076	50,076
R^2	0.76	0.77	0.77
Asthma	-1.64 [-2.69,-0.60]	-0.85 [-1.92,0.23]	-0.88 [-1.96,0.19]
Constant	22.62 [21.98,23.26]	22.47 [21.86,23.07]	-0.55 [-43.20,42.10]
N (observations)	50,076	50,076	50,076
R^2	0.69	0.70	0.70
Infectious gastroenteritis	1.32 [-0.19,2.84]	0.64 [-1.03,2.31]	0.58 [-1.09,2.25]
Constant	30.56 [29.58,31.54]	30.40 [29.48,31.32]	5.07 [-45.61,55.74]
N (observations)	37,476	37,476	37,476
R^2	0.73	0.74	0.74
Pneumonia	-0.82 [-2.68,1.04]	-0.94 [-2.84,0.97]	-1.01 [-2.91,0.89]
Constant	69.66 [68.55,70.78]	69.66 [68.58,70.75]	-52.72 [-119.35,13.91]
N (observations)	50,076	50,076	50,076
R^2	0.73	0.73	0.73
Controls			
Municipality and year fixed effects	Yes	Yes	Yes
State-by-year fixed effects	No	Yes	Yes
Time varying municipal controls	No	No	Yes

The key explanatory variable is a binary indicator that takes value 1 if there is at least one MDP physician serving at the municipality starting from the first year of enrollment in MDP and zero otherwise. Hospitalization data are extracted from the Hospital Information System of the public hospitals using ICD-10 groupings indicated in patient discharge records. 95%CIs are in brackets. All regressions include municipality fixed effects and state-time fixed effects. Time-varying municipality controls include the municipal GDP per capita (in log scale), hospital beds per 1,000 inhabitants, proportion of the population with private insurance plans, proportion of adult population ≥ 20 years of age and population size. All regressions include CEM weights. In all regressions, standard errors are clustered at the municipality level.

Chapter V:

Conclusion

This dissertation provided a comprehensive analysis of Brazil's More Doctors Program during its four years of implementation. This section summarizes the findings from the three studies and discusses policy implications, and suggests avenues for further research.

5.1. Summary findings

We started out by assessing the performance of community-targeting in the MDP from 2013 to 2017 (Chapter 2). This study was an important first step to generate evidence on the extent to which the MDP was able to reach the vulnerable communities it aimed to target. We showed that the MDP vulnerability criteria were able to group municipalities into two distinct categories (i.e. vulnerable vs. non-vulnerable) based on the level of socioeconomic development, the health system supply factors, and population characteristic. Also, we found that the MDP faced considerable challenges in community-level beneficiary targeting; only two thirds of municipalities with vulnerability designation joined MDP in its first four years of implementation, whereas one third of municipalities that were enrolled in the program did not match any of the program's vulnerability criteria. Our results are aligned with findings from Oliveira and colleagues (2016) that studied the MDP's beneficiary targeting performance between 2013 and 2014, and two recent reviews focusing on targeting methods used in social programs (Sabates-Wheeler *et al.* 2015; Devereux *et al.* 2017).

We demonstrated that the MDP had difficulty reaching vulnerable communities. The poverty rate was the highest among vulnerable municipalities that did not receive any MDP physicians. These municipalities also had the lowest supply of health infrastructure and primary care physician availability prior to the MDP. They were sparsely populated and smaller in size. Conversely, we showed that municipalities that received MDP physicians despite not meeting any of the vulnerability criteria had the highest levels of socioeconomic development and availability of health supplies and personnel.

These findings are in congruence with results from Andrade and colleagues (2018) that demonstrated that the level of socioeconomic development and population density were important factors that influenced uptake and expansion of the FHS.

Having studied the performance of community-targeting in the MDP in its first four years, we next turned our attention to the effects of MDP on population health over time (Chapters 3 and 4). In both studies, we relied on quasi-experimental designs to investigate how hospitalizations for avoidable causes would have changed in the MDP municipalities in the absence of the program.

Our descriptive findings demonstrated that hospitalizations for most health outcomes we studied declined from 2009 to 2017. For instance, for heart failure and hypertension, we observed declining trends in hospitalizations. Conversely, we showed that hospitalizations due to cerebrovascular diseases increased since 2009 (Chapter 3). For children and adolescents under 20 years of age, we observed declining trends in avoidable hospitalizations. We found that the decline in avoidable hospitalizations was four times that of the reduction in all-cause hospitalizations (Chapter 4). For this age group, the largest declines in hospitalizations were due to asthma, followed by pneumonia and infectious gastroenteritis.

We found mixed results on the effect of MDP on avoidable hospitalizations. We showed that the MDP did not guarantee reductions in hospitalizations for all health conditions we studied. For instance, we found that the MDP led to fewer hospitalizations due to cardiovascular diseases. But, we did not find evidence that the MDP was associated with any measurable reductions in heart failure and hypertension (Chapter 3). Similar to Fontes *et al.* 2018, we further demonstrated that it took time for the beneficial effects of the MDP to become observable and these effects accrued over time. Next, we showed that the MDP did not lead to reductions in avoidable hospitalizations for children and adolescents under 20 years of age (Chapter 4), even though the program was associated with increases in the number of primary care consultations for this age group. The finding that investing in primary care did not guarantee reductions in all health conditions is in line with earlier works focusing on the MDP (Mattos and Mazetto 2019; Maffioli *et al.* 2019), as well as earlier studies that demonstrated that the expansion of the FHS prior to the launch of MDP also did not guarantee reductions avoidable hospitalizations for all health conditions (Macinko *et al.* 2009; da Silva and Powell-Jackson 2017). In both studies, we found that rural municipalities benefited more from the MDP compared to urban communities.

5.2. Policy implications and avenues for further research

Dissertation findings have substantial applications to ongoing policy debates over health system reform in developing countries. Results from the second chapter suggest that policymakers may benefit from a careful consideration of the challenges and opportunities in deploying community-level targeting methods in large-scale programs. In Brazil, the use of an explicitly defined set of community-level criteria allowed the MOH team to leverage existing administrative data sources and lessons learned from implementing similar community-level targeting approaches in other social programs. However, it also came at the expense of accuracy in targeting. By considering two conceptually different versions of mistargeting, we highlighted that policymakers should consider the extent of both under-coverage(i.e. non-enrollment among target communities) and leakage (i.e. program enrollment among non-target communities). Quantifying the magnitude of under-coverage enabled us to generate evidence on the ability of MDP to reach the vulnerable communities. Quantifying the magnitude of leakage allowed us to ascertain the extent to which program resources were directed to non-target communities. While the targeting accuracy improved over time, non-target communities remained a considerable proportion of MDP beneficiaries. These findings are in line with earlier studies that highlight that the choice of beneficiary targeting method presents various trade-offs for policymakers (Sabates-Wheeler *et al*. 2015; Devereux *et al*. 2017).

Results from the last two studies highlight that implementing a large-scale program to expand access to primary care in underserved areas leads to gains in population health, even though our results are mixed. Results from Chapter 3 show that greater access to primary care physicians led to reductions in hospitalizations due to avoidable cardiovascular conditions. However, we did not find any evidence that the MDP led to reductions in avoidable hospitalizations due to heart failure and hypertension. Chapter 4 demonstrates that investing in primary care did not change hospitalizations due to avoidable conditions among children and adolescents under 20 years of age, though it contributed to the narrowing of urban-rural disparities.

The last two studies underscore that policymakers should consider the complexities in translating increased investment in resources devoted to primary care to improved health outcomes. We show that even with a large-scale primary care program that deployed a large number of physicians with prior training in family medicine in underserved communities, it still took time for the impact of the MDP on avoidable cardiovascular conditions to be observed, though we also demonstrate that the beneficial effects grew over time (Chapter 3). This finding is in line with results from Fontes *et al.* 2018 and Maffioli *et al.* 2019 that studied the impact of MDP on avoidable hospitalizations. Similarly, Cesur *et al.* 2017 similarly showed that in Turkey, the impact of the family medicine program in reducing mortality accumulated over time. Similar to Maffioli *et al. (*2019) and

Mattor and Mazetto (2019), we further found that the MDP did not guarantee measurable reductions in hospitalizations for all health conditions we examined or for all population groups.

Results of the last two studies suggested that strengthening primary care was more beneficial for rural communities than their urban counterparts. For instance, in rural municipalities, the beneficial impact of MDP on avoidable hospitalizations for cardiovascular conditions was greater in magnitude and became discernable earlier than in communities (Chapter 3). For children and adolescents under 20 years of age, the MDP was associated with fewer avoidable hospitalizations in rural municipalities, partly due to infectious gastroenteritis. But we found no evidence that the MDP led to reductions in avoidable hospitalizations for this age group in urban municipalities (Chapter 4). This finding is not surprising; the FHS has historically played a more crucial role in ensuring access to care in disadvantaged communities. Our findings are in congruence with earlier studies that demonstrate that efforts to strengthen primary care help reduce avoidable hospitalizations and reduce health disparities (Starfield 2012; Bastos *et al.* 2017).

We used avoidable hospitalizations as the main measure to examine the impact of the MDP on population health (Chapters 3 and 4). Chapter 3 focused on avoidable cardiovascular conditions, that together represent the leading cause of death in Brazil (Schmidt *et al.* 2011; IHME 2018) and most cardiovascular conditions, whereas Chapter 4 focused on avoidable conditions that have been shown to disproportionately affect children from low socioeconomic status (Rasella *et al.* 2010; Victora *et al.* 2011; Escobar *et al.* 2015; Wehrmeister *et al.* 2019). Results from these studies suggest that policymakers and researchers may consider using avoidable hospitalizations as a measure to track health system performance over time, as efforts to improve primary care provision move to a more prominent position in the aftermath of the Alma Ata 2.0 Declaration. Avoidable hospitalizations are already being used in many high-income countries as a measure of health system performance, though there is relatively little evidence from developing countries (Rosano *et al.* 2012). While this dissertation made use of a publicly available, municipal-aggregated administrative database, corresponding data may not exist in other settings. In these cases, countries may consider fielding surveys and using facility-level data.

This dissertation highlights the methodological challenges around examining the impact of a large-scale primary care program in the context of a highly decentralized developing country. A detailed analysis of the accuracy of beneficiary targeting (Chapter 2) was crucial to inform the study designs that deployed quasi-experimental methods (Chapters 3 and 4). We show that despite the stated objectives of the MDP in terms of targeting typically underserved communities, a considerable proportion of program beneficiaries were non-target municipalities (Chapter 2). This finding was particularly important for our decision to use of coarsened exact matching and difference-in-difference methods in conjunction. Our approach yielded study samples that are highly representative of the Brazilian population, while simultaneously addressing potential sources of bias due to non-random enrollment in the program. By doing so, it allowed us to overcome an important limitation of earlier studies. We hope that the new evidence provided in this dissertation can inform the design of future studies analyzing the effects of large-scale primary care programs.

This dissertation was unable to disentangle the extent to which the MDP may have impacted each aspect of primary care provision. Chapter 4 provided some empirical evidence on the number of primary care consultations to children and adolescents, but it did not examine whether the MDP led to improvements in other aspects of care. However, as discussed in Chapter 1, the MDP may have led to improvements in the comprehensiveness of care, if the FHS teams started to offer services that they may not have time to do so otherwise. Continuity of care may have improved due to the length of the MDP contracts spanning a 3-year period. The coordination of care may have also been influenced through increased referrals to specialists and emergency care services. The MDP may have influenced patient behaviors given that the FHS teams are engaged in health promotion and education activities. Future studies can explore the impacts of MDP on the practice of primary care and patients' health behaviors.

In the writing of this dissertation, a new large-scale primary care program called the *Médicos pelo Brasil* (MPS) replaced MDP. It was launched in December 2019 by the new elected government that took term in January 2019. Similar to the MDP, the MPS aims to address physician gaps in underserved municipalities. The MPS also uses community-level targeting methods to identify underserved communities, including the urbanization level of the municipality, population size, demographic density and distance of municipality from large urban centers (Brazil 2019). The lessons learned from this dissertation will pave the way for future studies to assess the extent to which challenges faced in the implementation of the MDP will be addressed by the MPS, and whether continued investment in primary care provision will lead to further improvements in population health.

This dissertation relates to the body of literature on the impact of investing in primary care on health system performance in developing countries. The dissertation findings underscore that the sizable infusion of resources in primary care in underserved settings can improve population health and reduce urban-rural disparities. By doing so, the dissertation provides new causal evidence from a developing country setting to ensure efforts to improve primary care provision come to a more prominent position towards achieving universal health coverage.

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