SSM - Population Health 12 (2020) 100695

Contents lists available at ScienceDirect

SSM - Population Health

journal homepage: http://www.elsevier.com/locate/ssmph

Impact of Brazil's More Doctors Program on hospitalizations for primary care sensitive cardiovascular conditions

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ARTICLE INFO

Keywords:
Brazil
Primary healthcare
More doctors program
Physician recruitment
Family health strategy

ABSTRACT

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. In this paper, we study the impact of Brazil's More Doctors Program (MDP) on hospitalizations due to cerebrovascular disease and hypertension. We exploit the geographic variation in the uptake of the MPD and combine coarsened exact matching and difference-in-difference methods to construct valid counterfactual estimates. 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 years from 2009 to 2017. Our analysis resulted in estimated coefficients of −1.47 (95%CI: −4.04,1.10) for hospitalizations for cerebrovascular disease and −1.20 (95%CI: −5.50,3.11) for hypertension, suggesting an inverse relationship between the MDP and hospitalizations. For cerebrovascular disease, the estimated MDP coefficient was −0.50 (95%CI: −2.94,1.95) in the year of program introduction, −5.21 (95%CI: −9.43,-0.99) and −8.21 (95%CI: −13.68,-2.75) in its third and fourth year of implementation, respectively. Our results further suggest that the beneficial impact of MDP on hospitalizations due to cerebrovascular disease became discernable in urban municipalities starting from the fourth year of implementation. We found no evidence that the MDP led to reductions in hospitalizations due to hypertension. Our results highlight that increased investment in resources devoted to primary care led to improvements in hospitalizations for selected cardiovascular conditions. However, it took time for the beneficial effects of the MDP to become discernable and the Program did not guarantee declines in hospitalizations for all cardiovascular conditions, suggesting that further improvements may be needed to enhance the beneficial impact of the MDP on the level and distribution of population health in Brazil.

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; Naghavi et al. 2017; Yusuf et al. 2014).

The Global Conference on Primary Health Care in 2018 renewed global commitment to strengthening primary care provision. 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, 2009; Starfield et al. 2005; Kringos et al. 2010, 2013; Kruk et al., 2010; Shi, 2012; Starfield, 2012; Doubova et al. 2016; Macinko 2019; Button et al. 2019).

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 (Ansari, 2007; Billings et al. 1993). Previous studies indicate that high rates of primary care sensitive 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; Ansari, 2007; Caminal et al. 2004; Laditka

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https://doi.org/10.1016/j.ssmph.2020.100695
Received 19 May 2020; Received in revised form 11 November 2020; Accepted 12 November 2020
Available online 18 November 2020

et al. 2003; Rosano et al. 2012). Yet, available evidence on the relationship between increased investment in primary care and the use of hospital services is mixed (Gibson et al. 2013; Rosano et al. 2012). Several studies found that there was an inverse relationship (Arrieta & García-Prado, 2015; Laditka et al. 2005; Rizza et al. 2007), whereas others showed a positive or no associations (Ricketts et al. 2001; Schreiber & Zielinski, 1997). Moreover, most empirical evidence comes from high-income settings, including the United States, Canada, Australia, and European health systems (Cloutier-Fisher et al. 2006; Friedberg et al. 2010; Glied & Smith, 2011; Kringos et al. 2010; Lopez et al. 2017; Magán et al. 2011; Purdy et al. 2009; Rosano et al. 2012; Weissman et al. 1992; Whittaker et al. 2016).

In this study, we address the gap in the literature by assessing the impact of Brazil's More Doctors Program (MDP) on hospitalizations for cardiovascular conditions. 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 (Andrade, Coelho, Xavier, & et al, 2018; Macinko & Harris, 2015). 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, Coelho, Xavier, & et al, 2018).

Established in 2013, the MDP was one of the world's largest health programs that aimed to strengthen primary care provision in traditionally underserved communities (Ministério da Saúde, 2019). The MDP had three main components. The first involved new funding for the construction of new primary health care clinics or refurbishing of existing ones to support health care provision on the ground. The second was the establishment of new medical school in underserved areas with a particular emphasis on primary care training. Finally, the third component 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. This feature provides a valuable opportunity to study the relationship between primary care physician availability and hospitalizations due to primary care sensitive conditions for selected cardiovascular conditions.

We identified the effect of the MDP by exploiting the geographic variation in the uptake of the program. As our main primary outcomes, we selected hospitalizations due to cerebrovascular disease and hypertension. Together, these two conditions represent close to half of all hospitalizations due to cardiovascular diseases between 2009 and 2017 in Brazil. To the best of our knowledge, this study provides the first causal evidence of the impact of the MDP on hospitalizations for these selected cardiovascular conditions.

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 (IHME, 2018; Victora et al. 2011). The burden of cardiovascular deaths is more pronounced in poorer regions of the country (Schmidt et al. 2011).

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 1000 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 that can help reduce the burden of cardiovascular diseases. For high-risk patients, the FHS teams can prescribe medication and monitor whether their 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 (Aquino et al. 2009; Bastos et al. 2017; Elias et al. 2008; Hone et al. 2017; Macinko et al. 2007; Nery et al. 2014; Rasella et al. 2010) with substantial reductions in hospitalizations for conditions sensitive to primary care (Cavalcante et al. 2018; Macinko et al. 2010, 2011) 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 more than 16 thousand domestic and 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 (Santos et al. 2018). The MDP relied particularly on foreign physicians who were recruited from more than 85 countries (Nogueira et al. 2016); more than half of about 16 thousand MDP physicians all MDP physicians (52%) were from Cuba (Santos et al. 2018).

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 recruited from other countries had prior experience in family medicine. Upon acceptance into the program, they enrolled in a mandatory three-week course. 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. Once placed in local communities, MDP physicians were required to practice medicine only within the organization of the FHS.

As shown in Fig. 1, the geographic coverage of the MDP expanded rapidly, with the proportion of municipalities that enrolled in the program increasing from almost 20% in 2013 to about 63% 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 (Özçelik et al. 2020). All municipalities were eligible to join the MDP; though they were required to submit an application to the MOH to receive MDP physicians. Once a municipality submitted their application, the MOH determined whether the municipality was among the priority communities and calculated the number of MDP physicians that would be allocated to the community (Özçelik et al. 2020).

Methods

Our main unit of analysis in the post-CEM sample is 5564 out of Brazil's 5570 municipalities in the period between 2009-2017. 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 Brazilian Institute of Geography and Statistics (IBGE). We used administrative records from the MOH to construct an indicator of the number of hospital beds per 1000 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. 2018a, 2018b). 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

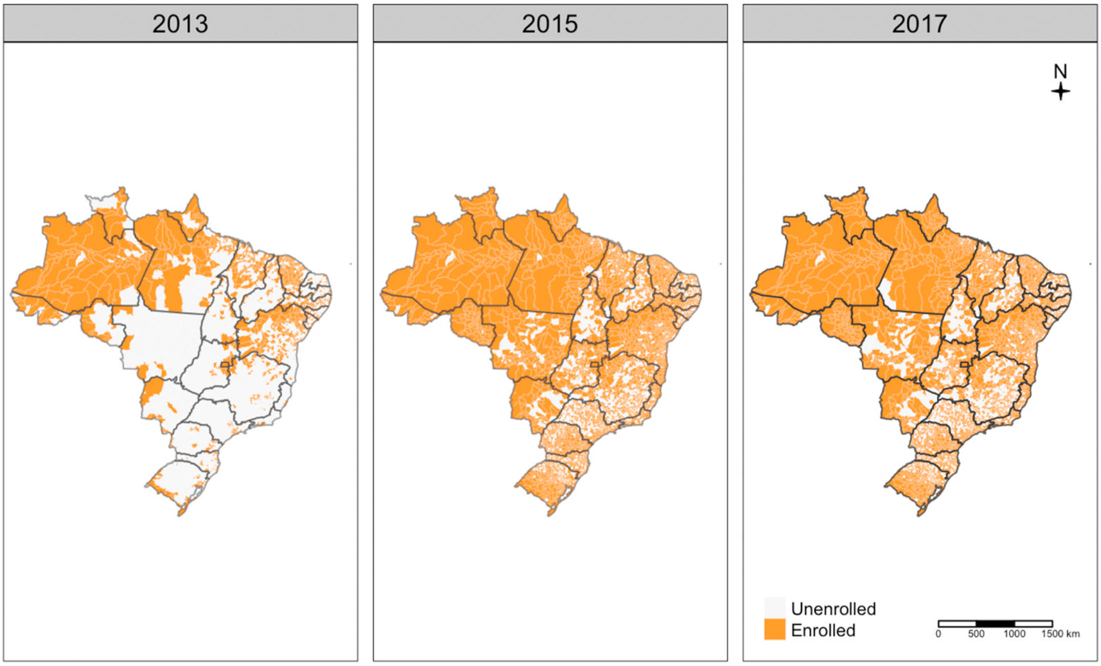

Fig. 1. The More Doctors Program implementation, 2013, 2015 and 2017.
Orange and white denotes municipalities enrolled and unenrolled in the program each year of implementation, respectively. Black lines indicate the state boundaries in Brazil.

also included controls for the proportion of population of population between 0-19 years of age, between 20 and 49 years of age, and 50 years and older provided by the IBGE. Population estimates by age groups were available for only the period from 2009 to 2015. We used the 2015 age distribution of municipalities in our calculations of age distributions in municipalities for 2016 and 2017. We opted for this approach, because we observed no substantial changes in the municipality age structure during the study period. 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: <5000 inhabitants, 5000–9999 inhabitants, 10,000–19,999 inhabitants, 20,000–49,999 inhabitants, and 50,000 or more inhabitants (A more detailed overview of covariates used in analysis is provided in the Appendix).

To classify location type of each municipality, 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). We opted for these classifications, because the MOH explicitly highlighted municipalities with rural settlements as among priority communities while distributing MDP resources (Ministério da Saúde, 2014; Özçelik et al. 2020). In this way, our analysis aims for consistency with the implementation of the MDP. Moreover, subgroup analyses provide evidence on the impact of the MDP on communities that were explicitly targeted.

Our primary outcome is the number of hospitalizations by municipality of residence for cardiovascular conditions sensitive to primary care per 100,000 inhabitants. In particular, we focused on cerebrovascular disease and hypertension, which combined represent almost half of hospitalizations due to cardiovascular diseases in our study period. 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 (Cavalcante et al. 2018; Dantas et al. 2018; Macinko et al. 2009; Ministério da Saúde, 2008). We scaled our outcome variables by population size, because the distribution of the number of hospitalizations was skewed. 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. 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 & Mcconnell, 2018).

In our study, we aim to construct valid estimates of counterfactual municipalities to ascertain how hospitalizations due to cerebrovascular disease and hypertension would have changed in the MDP municipalities in the absence of 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; Ku et al. 2019; Lindner & Mcconnell, 2018; Ryan et al. 2015, 2019; Stuart, 2010; Winship & Morgan, 2014; Yong et al. 2018). CEM enables us to reduce imbalances in the empirical distribution of observable characteristics between treatment and control municipalities by temporarily pruning data, while simultaneously retaining a representative sample. In our study, CEM is appealing, because it 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 & Nielsen, 2016; Stuart et al. 2014). Other advantages of CEM are explained in detail elsewhere (Blackwell et al. 2009; Chabé-Ferret, 2015; Iacus et al. 2012; King et al. 2011; O' neill et al., 2016; King & Nielsen, 2016; O'Neill et al. 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 (Andrade et al. 2018a, 2018b). We also included the proportion of population 20 years and above (Macinko et al. 2011) to account for demographic characteristics in each municipality (A more detailed description of CEM variables is provided in the Appendix). 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 rest of the difference-in-difference analyses. In our subgroup analysis, we applied the same CEM weighs from our main analysis that used location type as one of the matching variables, as was done by the MOH to identify high priority municipalities for the purposes of the MDP. In our analysis, treated municipalities were matched with untreated ones depending on whether depending on their classification as an urban/rural community.

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 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 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 (de Melo 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):

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

where Y_{mt} denotes the key hospitalization variables in municipality m in year t. X_{mt} is the vector of time-varying municipality controls that may be correlate with the outcome variables, including municipal GDP per capita, the number of hospital beds per 1000 inhabitants, the proportion of the population with private health plans, the proportion of the population aged 20 years and above, and population size. φ_m represents municipality fixed effects unobserved time-invariant municipality characteristics to account for permanent differences between municipalities that may correlate with key hospitalization outcomes. The term ρ_{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 ε_{mj} is the residual. The main parameter of interest in Equation (1) is the term γ, 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):

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

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 $\mathbf{MDP}^0_{mt}$, and the effects in subsequent years is captured by the estimated coefficients on $\beta_k MDP_{mt}$. 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 hospitalizations due to cerebrovascular disease and hypertension 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 analyses are detailed in the Appendix.

Results

Table 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 both outcomes, fewer hospital beds per 1000 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. We observed statistically significant differences in the empirical distribution of control variables for the municipal GDP per capita, hospital beds per 1000 inhabitants and the proportion of the population in different age categories. However, these differences were considerably smaller in the matched sample, as

Table 1
Descriptive statistics of Brazilian municipalities before and after CEM, 2009–2017.

	Full sample	Before CEM			After CEM	
		MDP	Non-MDP	p-values	Non-MDP	p-values
Panel A. Hospitalizations per 100 000 inhabitants						
Cerebrovascular disease	107.43	106.10	108.13	0.01	103.17	p < 0.001
	(80.40)	(76.27)	(82.50)		(78.90)	
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)	9.43	9.59	9.35	p < 0.001	9.31	p < 0.001
	(0.74)	(0.69)	(0.75)		(0.76)	
Hospital beds per 1000 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 population between 0-19 years of age	0.34	0.33	0.35	p < 0.001	0.36	p < 0.001
	(0.07)	(0.06)	(0.07)		(0.07)	
Proportion of population between 20-49 years of age	0.44	0.44	0.44	p < 0.001	0.44	p < 0.001
	(0.04)	(0.03)	(0.04)		(0.04)	
Proportion of population 50 years of age and above	0.22	0.23	0.22	p < 0.001	0.21	p < 0.001
	(0.06)	(0.06)	(0.06)		(0.06)	
Population size						
Less than 5000 (%)	0.23	0.16	0.26	p < 0.001	0.16	0.02
	(0.42)	(0.36)	(0.44)		(0.37)	
5000–9999 (%)	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	

shown in Table 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 2 presents the estimated impact of MDP on hospitalizations per 100,000 inhabitants. In Panel A, we find that the estimated MDP coefficients for hospitalizations for due to cerebrovascular disease and hypertension were −1.47 (95%CI: −4.04,1.10) and −1.20 (95%CI: −5.50,3.11) respectively, suggesting that neither estimate reached statistical significance (Results from different model specifications are presented in the Appendix). In Panel B, 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. For cerebrovascular disease, the estimated MDP coefficient was −0.50 (95%CI: −2.94,1.95) in the year of program introduction, −5.21 (95%CI: −9.43,-0.99) in its third year and it stood at −8.21 (95%CI: −13.68,-2.75) in the fourth year. This pattern suggests that, for cerebrovascular disease, 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. For hypertension, the estimated MDP coefficient was 0.27 (95%CI: −3.88, 4.42) in the year of program introduction. In subsequent years, we observed an inverse relationship between the MDP and hospitalizations, with the estimated coefficient shifting from −2.41 (95%CI: −7.43, 2.62) in the first year of implementation to −4.26 (95%CI: −73.96, 65.44) by the fourth year. However, none of these estimated MDP coefficients were statistically different from zero, suggesting that the MDP did not lead to any measurable declines in hospitalizations for this condition over time.

Table 3 presents results by location type. Panel A shows the MDP average treatment effects. In rural municipalities the estimated MDP coefficients for cerebrovascular disease and hypertension were −1.47 (95%CI: −5.44, 2.51) and −7.69 (95%CI: −15.30, 0.12), respectively. Whereas in urban municipalities, the estimated MDP coefficients were −1.23 (95%CI: −4.56, 2.11) for cerebrovascular disease and 2.09 (95% CI: −3.01,7.18) for hypertension. However, none of the estimated MDP

Table 2
Impact of the MDP on hospitalizations in the matched sample.

	(1)	(2)
	Cerebrovascular Disease	Hypertension
Panel A. Controls for time-varying municipality controls, municipality fixed effects, state-by-year fixed effects		
MDP implementation	−1.47	−1.20
	[−4.04,1.10]	[−5.50,3.11]
Constant	105.02	−4.03
	[39.20,170.84]	[−73.77,65.72]
N	50076	50076
R^2	0.65	0.65
Panel B. Controls for time-varying municipality controls, municipality fixed effects, state-by-year fixed effects		
MDP (Year 0)	−0.50	0.27
	[−2.94,1.95]	[−3.88,4.42]
MDP (*Year 1)*	−0.43	−2.41
	[−3.45,2.58]	[−7.43,2.62]
MDP (*Year 2)*	−1.93	−2.97
	[−5.53,1.68]	[−9.20,3.25]
MDP (*Year 3)*	−5.21	−1.97
	[−9.43,-0.99]	[−9.58,5.64]
MDP (*Year 4)*	−8.21	−1.28
	[−13.68,-2.75]	[−11.84,9.28]
Constant	105.36	−4.26
	[39.75,170.96]	[−73.96,65.44]
N	50076	50076
R^2	0.65	0.65

All regressions are performed with CEM weights. Outcome variables are hospitalizations per 100,000 inhabitants. Data on hospitalization outcomes are 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 1000 inhabitants, proportion of the population with private insurance plans, population size, proportion of population between 0-19 years of age, between 20 and 49 years of age, and 50 years and older. 95%CIs are in brackets. All standard errors are clustered at the municipality-level.

Table 3
Impact of the MDP on hospitalizations by type of residence.

	Rural		Urban	
	(1)	(2)	(3)	(4)
	CD	HP	CD	HP
Panel A				
MDP	−1.47	−7.59	−1.23	2.09
	[−5.44,2.51]	[−15.30,0.12]	[−4.56,2.11]	[−3.01,7.18]
Constant	−19.91	−58.14	163.88	23.34
	[−72.48,32.65]	[−175.72,59.44]	[87.31,240.46]	[−61.46,108.15]
N	18243	18243	31833	31833
R^2	0.67	0.67	0.63	0.64
MDP (Year 0)	−0.78	−2.86	0.07	1.77
	[−4.35,2.78]	[−11.07,5.35]	[−3.20,3.35]	[−2.49,6.04]
MDP (*Year 1)*	0.12	−9.29	−0.54	1.20
	[−4.62,4.86]	[−18.60,0.01]	[−4.44,3.36]	[−4.60,7.00]
MDP (*Year 2)*	−2.39	−14.61	−1.56	2.80
	[−8.20,3.43]	[-26.76,-2.45]	[−6.15,3.03]	[−4.35,9.96]
MDP (*Year 3)*	−5.42	−15.40	−5.09	3.12
	[−12.05,1.20]	[-31.16,0.37]	[−10.53,0.36]	[−5.04,11.28]
MDP (*Year 4)*	−7.49	−19.41	−8.58	6.17
	[−15.94,0.96]	[-39.19,0.37]	[−15.91,−1.26]	[−5.15,17.49]
Constant	−19.88	−58.61	164.66	23.04
	[−72.44,32.68]	[−176.24,59.01]	[88.24,241.08]	[−61.74,107.82]
N	18243	18243	31833	31833
R^2	0.67	0.67	0.63	0.64

All regressions are performed with CEM weights. Outcome variables are hospitalizations per 100,000 inhabitants. Data on hospitalization outcomes are 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 1000 inhabitants, proportion of the population with private insurance plans, population size, proportion of population between 0-19 years of age, between 20 and 49 years of age, and 50 years and older. 95%CIs are in brackets. All standard errors are clustered at the municipality-level.

coefficients were statistically different from zero. Panel B evaluates dynamic effects of the MDP on hospitalizations. In rural municipalities, the estimated MDP coefficients remained statistically insignificant for cerebrovascular disease and hypertension throughout the study period. In urban municipalities the MDP led to measurable reductions in hospitalizations due to cerebrovascular disease starting from the fourth year of implementation, with the estimated MDP of −8.58 (95%CI: −15.91, −1.26). For hypertension, none of the estimated MDP coefficients were statistically different from zero in municipalities classified as urban.

Fig. 2 plots the estimated coefficients from our event study analyses. For hospitalizations due to cerebrovascular disease and hypertension, none of the estimated coefficients in the pre-MDP period were statistically different from zero. (Event study point estimates are provided in the Appendix). 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.

Discussion

In this study, we evaluated the impact of Brazil's More Doctors Program on hospitalizations for cerebrovascular disease and hypertension using municipal-level data covering the period 2009–2017. We showed that the MDP was correlated with fewer hospitalizations due to cerebrovascular disease starting from the third year of program implementation. In urban municipalities, the beneficial impact of MDP on hospitalizations due to cerebrovascular disease became discernable in the fourth year. We found no evidence that the MDP was associated with statistically significant declines in hospitalizations due to hypertension.

Our study has several strengths. First, our study makes several methodological contributions to the literature on the MDP. We use several publicly available datasets to build a unique municipal-aggregated dataset for 5570 municipalities covering a period of 9 years. Second, we used coarsened exact matching to minimize potential bias in our estimates. Many studies evaluating the impact of MDP rely on propensity score matching to account for potential bias (Fontes et al., 2018; Mattos & Mazetto, 2019). However, an emerging body of evidence suggests that CEM offers important advantages over other matching methods (Blackwell et al. 2009; King & Nielsen, 2016). In our analysis, CEM enabled us to leverage our contextual information on the unique design and implementation features of the MDP while selecting variables used in matching. The matched sample was highly representative of the population, which was an important limitation of many earlier studies (Gonçalves et al., 2016; Fontes et al., 2018).

Second, to our knowledge, this is the first study that provides an analysis of the impact of MDP on hospitalizations for cerebrovascular disease and hypertension. We selected these conditions, because they represent close to half of all hospitalizations due to cardiovascular conditions in Brazil during the study period. Moreover, earlier works suggested that the expansion of the FHS in the past was associated with improvements in hospitalizations due to cardiovascular conditions, including cerebrovascular disease and hypertension (Cavalcante et al., 2018; Macinko et al. 2010, 2011). To date, Fontes et al. (2018) provided causal evidence on the effect of the MDP on hospitalizations due to all conditions considered to be sensitive to primary health care; 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 (Maffioli et al., 2019). More recently, Mattos and Mazetto (2019) using a sample of 2940 municipalities with populations of less than 500,000 inhabitants and showed that the MDP led to reductions in general hospitalizations between 2010 and 2015. However, the authors did not report on the extent to which the observed reductions in hospitalizations were due to ambulatory care sensitive conditions. Like earlier studies, we sought to provide causal evidence, and performed an in-depth analysis of the relationship between the MDP and hospitalizations for cerebrovascular diseases and hypertension. Our findings are in line with most studies that demonstrate that the scale-up of MDP led to reductions in hospitalizations,

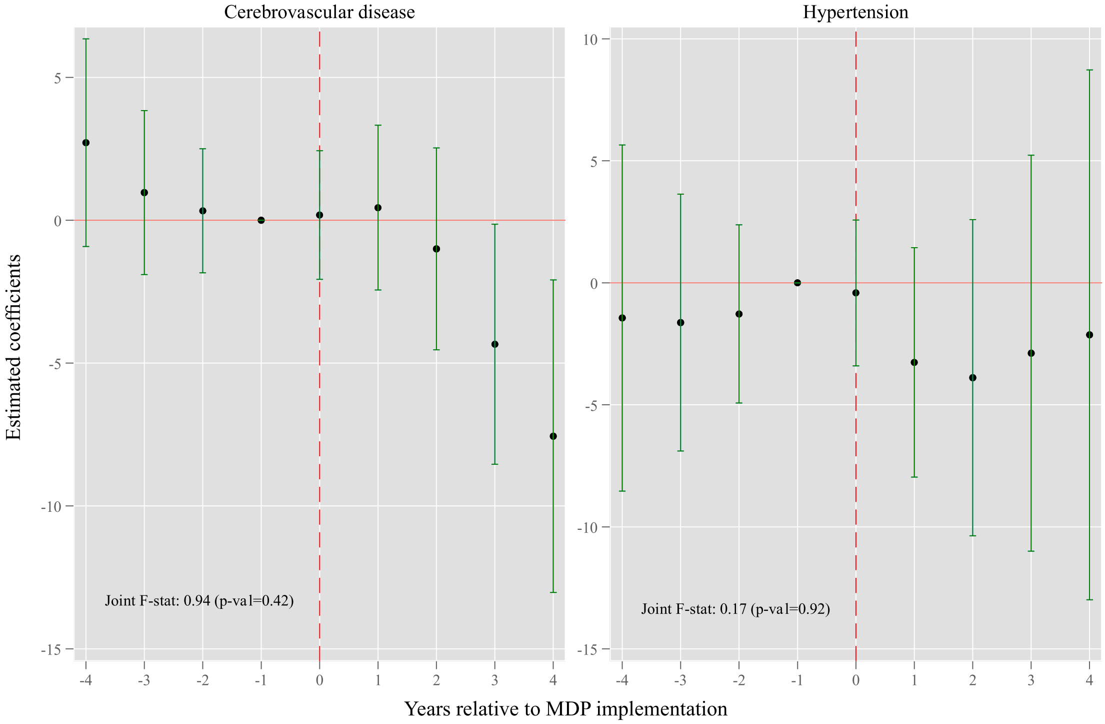

Fig. 2. Event study for hospitalization outcomes in the matched sample.
The estimated coefficients are relative to the year prior to the MDP implementation. The vertical dashed line indicates the start of MDP enrollment. Vertical bars around point estimates represent 95% confidence intervals. Estimated 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. All regressions are performed with CEM weights. Outcome variables are hospitalizations per 100,000 inhabitants. Data on hospitalization outcomes are 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 1000 inhabitants, proportion of the population with private insurance plans, population size, proportion of population between 0-19 years of age, between 20 and 49 years of age, and 50 years and older. 95%CIs are in brackets. All standard errors are clustered at the municipality-level.

thought it did not guarantee declines in hospitalizations for all health conditions and it took time for the beneficial effects to become observable.

Third, we provide new causal evidence on the differential impact of MDP between rural and urban communities. Earlier studies shed light on the heterogenous treatment effects of the MDP. For instance, Gonçalves and colleagues (2016) found that the observed reductions in hospitalizations attributable to the MDP were particularly prevalent in the Northeast region (e.g., diarrhea and gastroenteritis), where a large proportion of MDP physicians were deployed (Gonçalves et al., 2016). However, no study to date has looked whether the impact of the MDP differed across municipalities classified by the level of urbanization. Our study fills this gap by using classifications developed by the Ministry of Agrarian Development, as was done by the MOH to rank municipalities in accordance of their needs for the purposes of the MDP. We find that the MDP was associated with declines in hospitalizations due to cerebrovascular disease in urban municipalities in the fourth year of implementation.

We found no evidence that the MDP reduced hospitalizations for hypertension. This finding may be attributable to several factors. It is possible that the relatively short study period may not be sufficient enough time to start observing declines in hospitalization for this condition. Earlier studies with much longer study periods demonstrated an inverse relationship between the FHS expansion and hospitalizations due to cardiovascular conditions. For instance, Macinko et al. (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 selected cardiovascular conditions, including cerebrovascular diseases, heart failure, and hypertension. We also observed declines in 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).

Our study contributes to the strand of literature that explores the links between strengthening primary care and the burden of NCDs. Approximately 85% of premature mortality attributable to NCDs occur in low- and middle-income countries (Beaglehole et al., 2008). Yet, most evidence on the effectiveness of interventions to tackle the NCD burden comes from high-income settings. For instance, a recent analysis of reviews extracted from the Cochrane database found that only 13 out of 633 publications that examined the effectiveness of different approaches to address key NCD risk factors were from low-income settings, corresponding to less than 1% of study participants globally (Heneghan et al. 2013). In a more recent systematic review, Varghese et al. (2019) similarly alluded to the limit availability of evidence from these settings, despite the growing policy interest in primary care as a strategy to address the rising NCD burden (Kruk et al. 2015).

In recent years, a relatively rich body of literature focusing on the relationship between FHS and hospitalizations due to conditions sensitive to primary health care has emerged. Most evidence suggests that the expansion of the FHS was associated with improvements in population health (Bastos et al. 2017), while reductions in access to PHC services can lead to increases in the burden of mortality due to health conditions sensitive to timely and adequate access to primary care (Francesconi et al. 2020), as well as mortality from infectious diseases and nutritional deficiencies (Rasella et al. 2019). Our findings are aligned with this strand of literature, which demonstrated that the expansion of FHS services does not always lead to reductions in hospitalizations for conditions considered sensitive to primary care and it may take time before protective effects of the FHS become discernable (Cavalcante et al. 2018; Macinko et al. 2010, 2011).

Our study has some limitations. First, 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. 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.

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 et al. (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.

Our study focused on cause-specific 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. Moreover, 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 (Bittencourt et al. 2006, 2008; Mathias et al. 1998; Sgambatti et al. 2015).

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 1000 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 et al. (2009), we are unable to ascertain the remaining level of bias in our estimates in the absence of formal tests. One potential source of bias in our estimates stem from the MDP application process that required municipalities to apply to the MDP. If application process was burdensome, it may have led some municipalities to opt not to submit an application to join the program. The CEM aims to reduce potential bias due to the prioritization of municipalities by the MOH to inform decisions over the distribution of MDP physicians across communities, but this method does not address any remaining bias stemming from the decision of municipalities to apply to the Program.

Our study was unable to explore the potential mechanisms by which the MDP impacted hospitalizations for cardiovascular conditions due to the dearth of publicly available data. One plausible explanation for our finding that the MDP was associated with declines in hospitalizations for selected cardiovascular conditions may be due to increased interactions with the FHS workers. For instance, Mattos and Mazetto (2019) found that the MDP was associated with increases in the number of FHS consultations. However, the dearth of data precluded the authors from concluding that there were statistically significant increases in the number of primary care consultations that included health care services targeting cardiovascular health. Yet, recent evidence suggests that bottlenecks may exists in care provision for cardiovascular conditions. For instance, in a recent study focusing on hypertension care continuum in Brazil, Macinko et al. (2018) point out that substantial challenges in hypertension control persist. Medication adherence is low (Bastos-Barbosa et al., 2012), even though antihypertensive medications are accessible free of charge (Harris, 2012). Future studies are needed to explore the main challenges that hinder the provision of primary care services targeting cardiovascular conditions.

Our estimation strategy is unable to disentangle the complex interactions between the different design features of the MDP. Evaluating the impact of MDP is complicated by the complexity of its design, which entailed many changes in the delivery of primary health care provision that were introduced at the same time. For instance, one important design feature of the MDP was that its recruits were composed of physicians with prior training in primary care who were required attend training courses while they worked in their posts. While it is plausible that the explicit emphasis on physician education on primary care contributed to enhancing the impact of the MDP, our estimation strategy is unable to shed light on the importance of this factor relative to other changes implemented at the same time. This concern is not unique to the MDP; however, recent studies suggest that there is substantial variation across countries in terms of the design and implementation of programs to increase access to primary care vary substantially across settings (Bitton et al., 2019). As the evidence base on primary care continues to expand, future studies can document the design primary care programs to ascertain the extent to which different design aspects can change the impact of these programs.

We performed several robustness checks. First, we visually inspected and confirmed that there were similar trends in hospitalizations due to cerebrovascular diseases and hypertension between municipalities when grouped by the year of MDP enrollment and location type (i.e., urban and rural municipalities). We supplemented our visual inspection with several additional statistical analyses. First, we performed an event study as typically done in the literature (Borusyak & Jaravel, 2017; Goodman-Bacon, 2018; Roth, 2019). In this analysis, we tested whether the estimated coefficients in years prior to the MDP implementation reached statistical significance in the study sample, as well as separately for the rural and urban samples. The event study analyses suggested that the none of the estimated coefficients in the pre-MDP period for the selected outcomes did not reach statistical significance. Next, we performed joint significance tests further indicated that the estimated MDP coefficients prior to the implementation of the program were not statistically different from one another (We provide results from additional sensitivity checks in the Appendix). Taken together, these results lessen potential endogeneity concerns in our DID estimates.

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 health conditions. Our results suggested that sizable infusion of resources in primary care provision led to gains in population health. However, our findings also demonstrated that it took time for the MDP's beneficial effects to become discernable and that the Program fell short of yielding reductions in hospitalizations for all of the cardiovascular conditions we studied. Taken together, our findings suggest that further efforts may be needed to enhance the beneficial effects of the MDP on the level and distribution of population health in Brazil.

CRediT authorship contribution statement

Ece A. Özçelik: Conceptualization, Data curation, Methodology, Formal analysis, Writing - original draft. **Adriano Massuda:** Data curation, Writing - review & editing. **Margaret McConnell:** Conceptualization, Methodology, Writing - review & editing. **Marcia C. Castro:** Conceptualization, Methodology, Writing - review & editing, Supervision.

Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2020.100695.

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