PUBLIC HEALTH 166 (2019) 108–120

Available online at www.sciencedirect.com

Public Health

journal homepage: www.elsevier.com/puhe

Original Research

Effects of decentralization of primary health care on diabetes mellitus in Brazil

M. Nishijima [a,*], F.M. Sarti [a], I. Vodenska [b], G. Zhang [b]

[a] University of Sao Paulo, Brazil
[b] Metropolitan College, Boston University, USA

ARTICLE INFO

Article history:
Received 16 May 2018
Received in revised form
7 August 2018
Accepted 3 October 2018
Available online 23 November 2018

Keywords:
Diabetes
Public health care
Decentralization
Health access

ABSTRACT

Objectives: The aim of this study was to investigate the effects of primary healthcare decentralization on type 2 diabetes mellitus mortality and morbidity in different municipalities of a developing country.
Study design: This was a retrospective study based on a panel of annual data from 5560 Brazilian municipalities from 2000 to 2011.
Methods: The investigation used the staggered municipal adoption of a federal health information program as a quasi-experiment to identify the treatment effects of health decentralization on diabetes indicators. Using Difference-in-Differences models and instrumental variables, we analyzed the effects of primary healthcare decentralization on diabetes rates (i.e. diabetes deaths and hospitalizations by the number of people with a diabetes diagnosis and by population).
Results: Evidence suggests improvements in universal access to primary health care and progress in the average health outcomes related to diabetes mortality (reduction of 30%) and hospitalization (reduction of 2.3%) due to decentralization. Effects are further pronounced in developed regions with higher incomes, while the poorest and less developed regions showed virtually no effect.
Conclusions: These results demonstrate that there are particular preconditions for successful primary health decentralization, especially related to returns of scale (big health facilities are associated with low cost per treatment), lack of human and physical capital, and government coordination problems.

Introduction

The Brazilian Federal Health System (SUS), which is based on the provision of universal access to publicly funded health care for the population, was designed to decentralize primary health care to the municipalities in 1988 by the Brazilian Constitution. However, the administrative decentralization process has only been implemented intensively since 2000,

* *Corresponding author*. University of Sao Paulo, Av. Prof. Lúcio Martins Rodrigues, s/n, travessas 4 e 5. Cidade Universitária- CEP 05508-020, São Paulo, SP, Brazil. Tel.: +55(11) 3091 0526.
E-mail address: marislei@usp.br (M. Nishijima).
https://doi.org/10.1016/j.puhe.2018.10.005
0033-3506/

and around 40% of municipalities expenditures in health are still financed by the central government.

Under the assumption that decentralization can improve diabetes mellitus indicators, we investigated whether primary health decentralization to the municipalities in Brazil improved the local indicators of diabetes between 2000 and 2011.

We explored municipal staggered adoption of a federal innovative health information system (HIS) on hypertension and diabetes (the HiperDia program, launched in 2002), as a quasi-natural experiment on decentralization. Based on a framework of Difference-in-Differences (DD) models, we used the HiperDia adoption as an intervention that was able to measure the effects of decentralization on diabetes indicators. In addition, we identified the program effects using as instrumental variable (IV), the monthly average broadband accesses at the municipal level, to check the robustness of our estimates because the adoption of the program could be not random.

The HiperDia information system was designed to register and monitor hypertensive and diabetic patients allowing the municipality to receive additional federal funding for prevention, diagnosis, and treatment of the diseases (including drugs and other inputs to be freely distributed among the local population) according to the number of patients registered. In return, the municipalities were in charge of management of the program according to their priorities. In the absence of this HIS, a municipality deals with prevention and treatment for diabetes at the primary healthcare level in the same way as other health problems.

The HiperDia information system can be seen as a tool to focus on the targeted population diagnosed with diabetes and hypertension within the framework of the Family Health Strategy (FHS), an agent health program that allows the population to access the SUS. HiperDia adoption for a municipality was supposed to increase the efficiency and effectiveness of treatment and control of non-communicable diseases (NCDs) in primary healthcare decentralization to use public resources more efficiently.

An additional rule on types of medication and inputs distributed for diabetes treatment and control was implemented in 2007 (Administrative Rule 2583), precisely defining the medication (i.e. glibenclamide, metformin hydrochloride, human insulin NPH, and regular human insulin) and the inputs (i.e. syringes with attached needle for insulin delivery, test strips for measuring blood glucose, and lancets for finger sticks) made available at public sector health facilities. It should be noted that free drugs for treatment include only drugs without patents and therefore old technology.

Given the high cost of diabetes treatment and the lack of evidence regarding evolution in healthcare indicators of NCDs in a developing country undergoing health system decentralization and universalization processes, it is valuable to have a greater understanding of the effects of primary health decentralization on diabetes type 2 indicators. This is especially important when taking into consideration that part of the Brazilian population has been increasingly adopting lifestyles similar to developed countries, while most of its population still subsists in deprived conditions.

Background

Indications that diabetes may be positively impacted by primary healthcare supply are connected to the preventive characteristics of NCDs because primary health care comprises prevention as its main component.[1–3] Implementation of primary healthcare policies is a general aim in the decentralization of health systems. The following are types of disease prevention and control: (i) primary prevention (i.e. minimization of exposure to risk factors—promotion of healthy lifestyles); (ii) secondary prevention (i.e. the identification of complications derived from existing risk factors—diagnosis and education programs); and (iii) tertiary prevention (i.e. avoidance of complications—rehabilitation and disease management).[2,4]

In this study, we focus on diabetes because of its specific etiology (connected to obesity and overweight), substantial prevalence, and considerable comorbidities, which represent mounting costs to health systems worldwide, especially for monitoring blood glucose and medication.[2]

Most of diabetes cases are categorized into two types: type 1 diabetes, caused by a deficiency of insulin secretion, and type 2 diabetes (also known as diabetes mellitus), caused by a combination of cellular resistance to insulin action and inadequate compensatory insulin secretory response.[5] Our study investigates type 2 diabetes as this represents 90–95% of cases among adults in the population and is thus the prevalent type of the disease.

Type 2 diabetes poses a challenge for public health because of its escalation in prevalence worldwide and the costs involved in its monitoring, treatment, and complications related to comorbidities.[6] Diabetes has been imposing huge burdens on national health systems and household economies, especially in Latin American countries, where 25% of health expenditures are dedicated to treatment of diabetes and related complications. Approximately 10% of the Brazilian population have diabetes, and healthcare costs related to its treatment were approximately 1.7% of the GDP in 2015, being projected to reach 2.0% of the GDP in 2030.[7] In total, 72% of deaths in Brazil are due to NCDs.[8]

During the last three decades, there have been significant changes in the epidemiologic patterns of the Brazilian population along with demographic and nutritional transitions which led to the increasing prevalence of NCDs, especially diabetes and hypertension.[2] In addition, problems with contagious infectious diseases still remain, thus resulting in diverse characteristics of the diseases occurring in the country, which is a situation also identified in other developing countries. Furthermore, modifications in public financing and management of the health system has resulted in an increase of public expenditures for health care in Brazil.[9,10]

Trends in the prevalence of NCDs have been rising substantially over time linked to growth in the occurrence of obesity and overweight worldwide. Additionally, monitoring and treatment of NCDs have been evolving, and thus survival prognosis has steadily improved. This creates a paradoxical situation of improvements in patients' health status followed closely by the increased probability of comorbidities and rising healthcare costs for the health system.[2,6]

Diabetes has been one of the most prevalent NCDs worldwide, encompassing a group of metabolic diseases characterized by high blood glucose resulting from problems in insulin secretion, insulin action, or both. The monitoring and control of diabetes refers to the maintenance of blood glucose levels within acceptable ranges, thus avoiding extensive damages to vital organs, especially the eyes, kidneys, nerves, heart, and blood vessels.[5]

In addition, diabetes treatment costs have been growing rapidly in recent decades, particularly because of increases in the prices of medications. According to International Medical Statistics, the share of expenditures on antidiabetic medications was 3.6% in 2007, rising to 7.6% in 2015, thus becoming the second largest category of medications in global sales.

The impact of diabetes care costs on the Brazilian health system may compromise the premise of free universal health care financed by the public sector for the population, as specified in the 1988 Brazilian Constitution.[9,10] This may also be the case in other countries with similar universal health systems. Thus, it is crucial to evaluate the effects of primary healthcare decentralization on diabetes indicators to ascertain how effective it was to improve population health indicators.

The SUS was designed in 1988 to encompass predominantly public sector–funded health care intended to provide universal and free health care to the population supplemented by private sector activities. A gradual decentralization process was implemented throughout the ensuing decades, especially management decentralization during the mid-1990s onwards and financial decentralization post-2000 including assurance of fund transfers from national and state governments to municipalities.[9,10] However, because of the lack of their own fiscal revenues on the part of diverse Brazilian municipalities to finance the health system, approximately 40% of the financial support of the health system in 2011 was still based on central government transfers.

The Brazilian federal government is responsible for planning, financing, and setting priorities in health policies and programs at the national level and also for providing supplementary financial support for local health systems at the state and municipal levels. Municipal governments are responsible for the execution and accountability of primary healthcare programs, and state governments usually provide conditions for local governments to jointly supply medium- and high-complexity health assistance to the population. The complexity of the funding and management structure established within the SUS results in diminished decision-making autonomy at the local level, which could be described as an assisted decentralization model.[9,10]

The Brazilian central government also controls funding, acquisition, and distribution of diverse medications and other health inputs within the national program Popular Pharmacy (Farmacia Popular), which are delivered for the population at municipal level health facilities. This includes provision of resources for treatment, control, and prevention of diabetes and hypertension for eligible population groups and improvement of central government control on municipal governments. The municipalities, on the other hand, are in charge of providing and administering health treatments, services, and human resources.[10,11]

Several studies have investigated the associations between infant mortality and access to primary health care within the process of decentralization of health system management in Brazilian municipalities throughout recent decades. They show evidence of significant positive effects on infant mortality due to primary healthcare decentralization and on the implementation of the FHS, which has not yet been completed. The FHS is a policy designed to comprise the gateway to access health assistance within publicly financed health organizations.[12–16] However, while these studies report important findings on infant mortality, there is a lack of evidence of the effects of decentralization on chronic NCDs in developing countries. Diabetes, in particular, is a growing public health problem that may impose diverse burdens on health system policies because of its singular features in therapeutic management.[3,9,10]

Classical arguments in favor of public sector decentralization indicate that provision of public goods may be efficient at the local level, under assumptions of heterogeneous preferences and absence of spillovers, considering that local governments may have better information regarding their populations' needs in comparison to centralized government models.[17,18]

Nevertheless, there are also numerous arguments against decentralization indicating that its results may be influenced by diverse socio-economic, political, and demographic characteristics. Advantages of decentralization refer to low-cost solutions connected to coordination problems, that is, decentralization is undesirable for situations marked by high urgency or lack of relevant private information.[19]

Technical differences among local governments may also determine the capacity for the provision of public services contributing to the observation of diverse results of decentralization[20] which may be significantly influenced by the local level of competition.[21] Centralization is usually the better option in the presence of positive spillovers and economies of scale.[22]

Additionally, decentralization processes in developing countries may be different in comparison to developed countries. The differences of outcomes observed in various countries are as a result of the role of organizations and institutional contexts with diverse incentives.[21]

The benefits of decentralization processes analyzed in the economic literature usually present trade-offs; considering fiscal federalism, centralization is based on exploration of economies of scale, while political economy analysis of decentralization focuses on transaction costs and agency costs resulting from bureaucracy in developing countries.[21] Also, the absence of accountability in developing countries may favor the interests of local elites to the detriment of improvements of population welfare because of the possibility of political power capture at the municipal level. Hence, the results of decentralization in developing countries tend to be heterogeneous according to the political configuration.

Regarding decentralization in health systems, there are equally important arguments in favor of and against decentralization of health systems management.[23] There is evidence that decentralization of health systems is usually related to diverse models of healthcare financing, delivery, and management derived from varied socio-economic and political factors resulting in assorted degrees of efficiency and outcomes.[24]

Studies investigating decentralization of health systems usually focus on its improvements of responsiveness, efficiency, and effectiveness in service delivery. Major problems in the structure of institutional incentives related to principal–agent relationships influence the dynamics of performance in health systems, potentially leading to complications related to corruption and patronage under decentralization models.[25,26]

Other studies indicate important positive effects of fiscal decentralization on the satisfaction of the population and perception of the health system. The effects of political decentralization, however, are highly conditional on the authority and capacity of local governments regarding principal–agent relationships within the national health system.[27]

Local institutions directed toward health assistance accountability and government funding structure designed to enhance incentives for performance and efficiency may be instruments to promote decentralization of health systems while minimizing the risks of principal-agent problems.[28]

The use of locally available health information may support improvements in district-level decision-making to meet the health expectations and needs of a local population. Nevertheless, there are important challenges related to the availability and quality of data, human resources, and financial constraints; thus, evidence shows the limited range of decision-making processes, including the use of health data at the district level in low-income regions.[29]

In many countries, decentralization of decision-making and operational responsibilities of the health sector to subnational governments has resulted in disproportionate bureaucracy and politicization, whereas centralization of health policy to national governments impeded improvements in quality, safety, and efficiency of healthcare delivery because of managerial deficiencies at the regional level. Conversely, centralized imposition of patterns for health assistance at the national level may be unsuccessful because of the alienation of health professionals, populations, and patients comprising interest groups directed to influence decision-making processes at the municipal level.[23]

Other shortcomings that may be potentially associated with decentralization of health systems are lack of local infrastructure to meet the health needs of the population, excessive focus on curative care to obtain short-term health outcomes, and fragmentation of health assistance due to overspecialization causing lack of patient follow-up. On the other hand, decentralization of health system management to local levels may provide advances in social participation, promoting accountability in health policy.[2]

Methods

Data

We performed a retrospective study based on a panel of annual data from 5560 Brazilian municipalities from 2000 to 2011. Our data set was compiled from various official government sources, including the Department of Information of the Brazilian Unified Health System, the Brazilian Institute for Geography and Statistics, and the Brazilian Regulatory Agency for Telecommunications.

Primary health care was the main target for health system decentralization within SUS, including activities for health promotion and disease prevention (e.g. monitoring and control of diabetes, hypertension, and other chronic and infectious diseases at the municipal level).

The FHS was initiated in 1994 under the designation of the Family Health Program based on household visits by multidisciplinary health professional teams to promote universal health coverage through widening access to SUS. However, the FHS only spread significantly in Brazil after 2000 (see Fig. A1 in the Appendix). The FHS represents the gateway to the population for accessing medium- and high-complexity health care, through registration and follow-up of primary health services users.[10,11]

HiperDia operated from 2002 until 2011, encompassing data on individuals diagnosed with hypertension and/or diabetes covered by the FHS program. It was designed to provide tools for the prevention of comorbidities and complications associated with uncontrolled chronic diseases by monitoring information on health conditions and tracking medication prescriptions.

As a result of HiperDia being an information system tool, which was heavily based on computation skills, its adoption was staggered over time to allow training of human resources at the municipal level. Approximately 84% of the nation's municipalities adopted HiperDia in 2002. However, actual municipal adoption of HiperDia was connected to municipal FHS implementation because HiperDia ran inside the FHS program. FHS is the main gateway for the population to access the public system for health care in Brazil (SUS), which was also in the process of expansion; thus, the full capabilities of the HiperDia program depended on the FHS program.

Models

Considering the endogeneity problem related to determining the effects of decentralization of health care on health indicators, because of particular reasons that could incentivize a municipality to decentralize first, we employed the HiperDia as an intervention policy that brings exogeneity to the explained variable. Disregarding the endogeneity problem, decentralization estimates on outcomes may be biased. Thus, using a shock on decentralization, the staggered adoption of a federal information health system as a quasi-natural experiment in our case allows us to identify the unique effect of decentralization on municipal diabetes indicators, since the program is a policy intervention.

To measure the intervention, we employ DD models that are able to ascertain difference in time (before and after) and between groups (treated and non-treated).[30] However, since the staggered adoption of the HiperDia Program may not be fully exogenous, we also employ an IVs framework to check the robustness of the results.[30]

To make our intervention variable precise, we use the HiperDia program staggered adoption by municipalities crossed with FHS adoption as a variable representing decentralization (our intervention variable) because, as explained earlier, the FHS is the main channel where HiperDia operates. However, we keep the FHS as a dependent variable to control for the access of the population to the public health system.

The staggered adoption of HiperDia by municipalities according to their capacity to enter the program and the proportion of population covered by the FHS program allowed us to identify the timing of the program adoption. Municipalities offering an information system with many capabilities, free distribution of medication, and inputs for diabetes monitoring and control was progressively achieved from 2002 onward, and according to the municipality structure, both due to the period of HiperDia adoption and FHS program coverage. Therefore, based on the combination of data on HiperDia adoption and FHS program coverage at the municipal level, we propose two indices of adoption that comprise accurate measures for the HiperDia intervention:

1. Adoption: binary variable (value = 1, if the municipality adopted HiperDia, and FHS was operating at a certain year onward and value = 0, if otherwise);
2. Adoption in years: count variable for the number of years since the municipality adopted HiperDia and FHS was operating.

We consider that the effect of the HiperDia program was a decentralization shock on health indicators of diabetes in Brazilian municipalities, distinguishing treatment and control groups. Municipalities that adopted HiperDia and were covered by the FHS composed the treatment group, while municipalities that either did not adopt HiperDia or adopted but were not covered by the FHS composed the control group, according to the indices of HiperDia adoption.

We estimated baseline models using ordinary least squares (OLS) in DD with multiple times of interventions:

$$I_{it} = \alpha_0 + \alpha_1 hd_{it} + \alpha_2 \lambda_{it} + \alpha' X_{it} + u_{it} \tag{1}$$

where:

I_{it} is diabetes indicators of the municipality i in year t;
hd_{it} is 1 if municipality i adhered to HiperDia and was covered by FHS in the year t onwards, and 0 c.c.;
λ_{it} is a set of time control variables;
X_{it} is a set of control variables of the municipality i in the year t;
u_{it} is an error term.

The set of control variables X_{it} includes FHS program coverage, gross domestic product (GDP) per capita (as a proxy for income per capita), health expenditure per capita, proportion of individuals aged above 40 years (control variable for age of increased risk of diabetes and higher prevalence of obesity), educational attainment of municipality mayor (college or higher), population, proportion of municipal resources on global health expenditures of the public sector (representing financial decentralization), proportion of illiteracy among adults (individuals aged above 15 years), year dummies, state dummies, and crossed dummies of years and states. We also use controls for interactions among period and location of the municipality to account for observed and unobserved factors at the year and state level, which may also influence health indicators of diabetes.

The coefficient of interest in the analysis was α_1, which reports the effect of HiperDia adoption among municipalities in the treatment group in comparison to municipalities in the control group.

To avoid confounding increases in the registry of diabetes by expansion in diabetes prevalence and improvement of treatment quality, we adopted diabetes indicators in per prevalence (number of deaths and hospitalizations due to diabetes among people with diabetes diagnoses) and per capita terms (number of deaths and hospitalizations due to diabetes among the population). Doing so, we handle the problem of increasing population coverage in the public health system during the period due to the decentralization process. We expect improvements in rates per diabetes prevalence and worsening or unchanging rates per population due to simultaneous increases in the number of individuals accessing the public health system and in the effectiveness of the health system. Diabetes mortality and hospitalization rates follow trends in this direction, and the incidence per capita (number of diabetes cases among the population) increased with municipalities' adoption of HiperDia.

Because there are significant differences in infrastructure and economic and sociodemographic characteristics among Brazilian regions resulting from an extremely unequal pattern of regional and personal income distribution, we split the sample into macroregions to estimate Eq. (1) and investigate whether the effects of HiperDia reflect these differences according to the region. Brazil has five macroregions: the Southeast and South regions are the richest; the Midwest region used to be poor but has improved recently because of food production systems; and the North and Northeast regions are the poorest. We also estimated Eq. (1) using the number of years that HiperDia had been adopted by the municipality to allow an evaluation of long-term results of decentralization.

We identified the estimates to check the robustness of results, considering that potential endogeneity may be connected to (i) a simultaneity problem: similarly to the influence of HiperDia adoption on diabetes indicators, the decision to adopt HiperDia may be impacted either by very poor health indicators at the population level in underserved municipalities or by superior infrastructure in developed municipalities that have the ability to deal with HIS and (ii) omission of variables: even when controlling for diverse variables, there could be omitted municipal-level variables in regression models for diabetes indicators. If some omitted variables are correlated with HiperDia adoption, the essential assumption for OLS efficiency is that $cov(x, u) = 0$ would be violated for the performance equation.

To check potential endogeneity and evaluate the robustness of the estimates, we used the IV method, a traditional framework which substitutes the endogenous variable by another correlated variable free of potential non-desirable correlations.[30] As we need a variable correlated with the HiperDia adoption but not correlated with the diabetes indicator, we use the future number of broadband connections as our IV, since the HiperDia is a HIS that requires computational and Internet skills. We use, however, the future number of broadband connections, bb, from 2007 to 2017, because broadband was set officially in Brazil only around 2006. Thus, this variable comprises a measure of future ability to deal with HIS that is crossed with FHS adoption, fhs, to generate our instrument. Note that the broadband is correlated with the adoption of a HIS, but not to health indicators.

Thus, we estimated adoption to HiperDia as follows:

$$hd_{it} = \gamma_0 + \gamma_1 bb_{it} + \gamma_2 (bb \cdot fhs)_{it} + \gamma\, X_{it} + v_{it} \tag{2}$$

We used the predicted value of the HiperDia adoption variable from Eq. (2) as the IV for adoption in Eq. (1). Assuming the validity of our IV, the underlying argument is that after controlling for factors that influence HiperDia adoption the IV may be treated as exogenous in determining diabetes indicators in Eq. (1).

Results

Table 1 summarizes our data and sources.

The results must be read while considering that HiperDia adoption and access to the public health system were widening simultaneously. Fig. 1 illustrates the evolution of diabetes prevalence in Brazilian municipalities during the period under review.

The results of the baseline models suggested improvements in diabetes mortality and hospitalizations per prevalence (number of registered diabetes cases) and negative impacts (positive coefficients) on diabetes mortality, hospitalizations, and diabetes incidence per capita in Brazil during the period (Table 2).

However, the results must be interpreted considering the growth of population coverage in the public health system throughout the decade. First, the diabetes prevalence grew significantly, particularly at the beginning of the decade (Fig. 2).

The prevalence of diabetes grew faster than its mortality and hospitalization rates because of increased access to diabetes diagnoses and treatment. In part, this represents an improvement in diabetes treatment regarding prevention of mortality and hospitalizations which are connected with best practices of primary health care.

On the other hand, HiperDia positively impacted mortality and hospitalization rates per capita due to diabetes because wider healthcare access allowed expansion of diagnosis and increased treatment coverage in the health system as a consequence of health system decentralization. The estimates of Table 2 result in a reduction of 30% in diabetes deaths rate and a reduction in hospitalization rates among people with diabetes of 2.3% due to primary health decentralization in Brazil. In this sense, HiperDia may still be considered a successful program because of its spread coverage of diabetes diagnosis and treatment in the population. See Fig. A2 in the Appendix for trends in diabetes rates.

Regarding the long-term effects of adoption of HiperDia, it is possible to conclude that the effects of HIS adoption decreased with time, although they were still significant (Table 3). The benefits of decentralization have such

Table 1 – Data description: variables according to function.

Variables description	N	Mean	Std. Dev.	Min.	Max.	Source
Health indicators of diabetes						
Diabetes deaths per prevalence	52,789	0.199	0.555	0.00	39.24	DATASUS
Diabetes hospitalizations per prevalence	52,675	0.038	0.110	0.00	7.32	DATASUS
Diabetes deaths per capita	66,612	0.000	0.000	0.00	0.00	DATASUS
Diabetes hospitalizations per capita	66,452	0.004	0.005	0.00	0.20	DATASUS
Diabetes prevalence per capita	62,098	0.014	0.090	0.00	18.38	DATASUS
Control variables						
FHS coverage	67,104	0.871	0.335	0.00	1.00	DATASUS
Population aged ≥40 years (%)	66,695	0.298	0.062	0.11	0.57	IBGE
Population (log)	66,695	9.374	1.142	6.49	16.24	IBGE
Municipal expenditures on health (%)	65,604	0.625	0.168	0.00	1.00	DATASUS
Illiteracy (% of individuals aged ≥15 years)	66,186	0.185	0.112	0.01	0.63	DATASUS
Health expenditure per capita (log)	65,793	4.836	−0.546	2.37	7.31	DATASUS
Mayor education (college or higher)	67,104	0.365	0.481	0.00	1.00	IBGE
Income per capita (log)	66,695	1.358	−0.741	0.44	5.21	IBGE
Treatment variables						
Adoption of HiperDia	66,768	0.789	0.408	0.00	1.00	DATASUS
Adoption of HiperDia measured in years	67,092	4.113	3.446	0.00	10.00	DATASUS
Crossed variable HiperDia and ESF average	66,768	0.739	0.439	0.00	1.00	DATASUS
Instrumental variable						
Monthly average of broadband accesses at municipality (log) 2007–2017	66,416	0.5001	0.5000	0.00	1.00	ANATEL

ANATEL, Brazilian Regulatory Agency for Telecommunications; DATASUS, Department of Information of the Brazilian Unified Health System; HiperDia, hypertension and diabetes health information system; IBGE, Brazilian Institute for Geography and Statistics; Max. maximum; Min., minimum; Std. Dev., standard deviation.

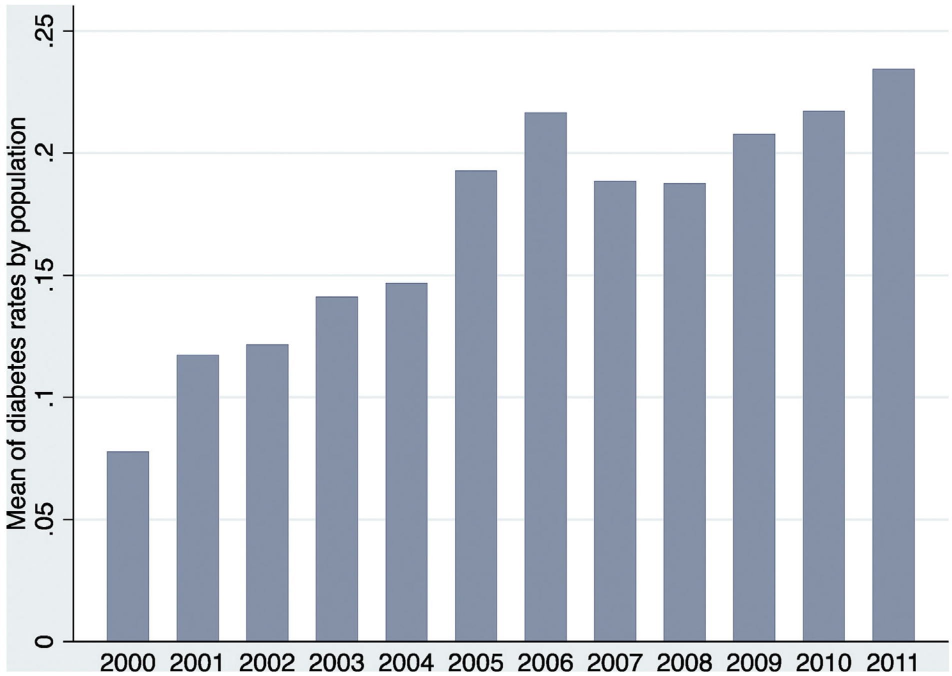

Fig. 1 – Evolution of municipal means of diabetes prevalence in the Brazilian population (2000–2011). Source: DATASUS, Brazilian Ministry of Health.

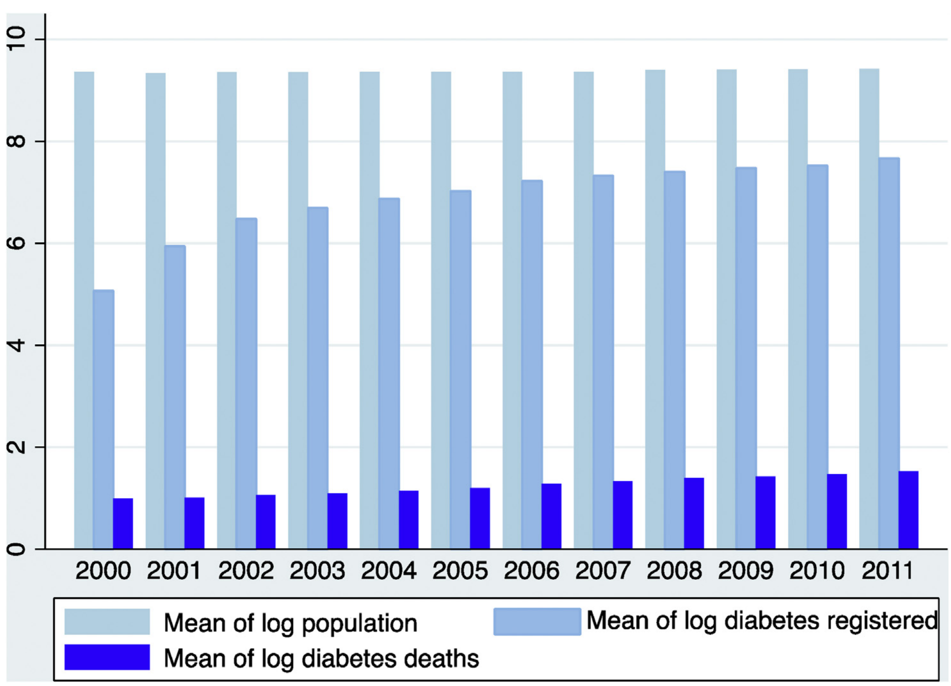

Fig. 2 – Logarithm of population, diabetes cases registered (prevalence), and mortality rate due to diabetes (2000–2011).

decreasing returns because patients who start receiving treatment tend to be without further changes in health care.

Heterogeneous impact among regions

Considering geographical inequalities in access to health assistance in Brazil,[27] we split the sample into five macro regions to estimate Eq. (1) (Table 4). The results confirm that the effects of HiperDia are higher and statistically significant for the Southeast and South regions, the richest and more developed parts of Brazil, in comparison to the remaining poorer regions.

The evidence is similar to the study by Galiani et al.,[20] who argue that the success of decentralization depends on local infrastructure and human capital, among other factors.

Table 2 – Difference-in-Differences estimates for diabetes outcomes indicators, according to HiperDia adoption (2000–2011).

Variables	Diabetes deaths per prevalence	Diabetes hospitalizations per prevalence	Diabetes deaths per capita	Diabetes hospitalizations per capita	Diabetes prevalence per capita
HiperDia adoption	−0.0609** (0.024)	−0.0088** (0.004)	0.00001* (0.000)	0.0003** (0.000)	0.0019*** (0.001)
FHS adoption	−0.0657* (0.038)	−0.0210** (0.009)	0.0000 (0.000)	−0.0001 (0.000)	0.0009** (0.000)
Population aged ≥40 years (%)	0.1786 (0.119)	−0.0129 (0.024)	0.0011*** (0.000)	0.0149*** (0.001)	0.0591*** (0.005)
Population (log)	0.1230*** (0.017)	0.0248*** (0.003)	0.0000*** (0.000)	0.0002*** (0.000)	−0.0028*** (0.000)
Municipal expenditures on health (%)	0.2515*** (0.046)	0.0422*** (0.010)	−0.0001*** (0.000)	−0.0016*** (0.000)	−0.0078*** (0.002)
Illiteracy (% of individuals aged ≥15 years)	−0.0564 (0.052)	−0.0055 (0.010)	0.0000 (0.000)	0.0003 (0.000)	−0.0028 (0.003)
Health expenditure per capita (log)	0.0339* (0.020)	0.0019 (0.004)	−0.0000*** (0.000)	−0.0006*** (0.000)	0.0021*** (0.001)
Mayor education (college or higher)	−0.0081 (0.008)	−0.0032** (0.002)	0.0000** (0.000)	−0.0000 (0.000)	−0.0003 (0.001)
Income per capita (log)	−0.0169* (0.009)	−0.0041* (0.002)	0.0000*** (0.000)	0.0001* (0.000)	0.0018*** (0.001)
Constant	−1.0719*** (0.259)	−0.0618 (0.067)	−0.0002*** (0.000)	0.0017** (0.001)	0.0094 (0.006)
N	51,257	51,134	64,665	64,496	60,283
R-squared	0.077	0.109	0.171	0.116	0.008

***$P < 0.01$; **$P < 0.05$; *$P < 0.1$.
FHS, Family Health Strategy; HiperDia, hypertension and diabetes health information system.
Robust standard errors in brackets (clusters on the municipal level).
Control variables included dummies of state, year, and their interactions.

Table 3 – Difference-in-Differences estimates for diabetes outcomes indicators, according to years of adoption to HiperDia (2000–2011).

Variables	Diabetes deaths per prevalence	Diabetes hospitalizations per prevalence	Diabetes deaths per capita	Diabetes hospitalizations per capita	Diabetes prevalence (per capita)
HiperDia adoption	−0.0103** (0.004)	−0.0014** (0.001)	0.0000** (0.000)	0.0001*** (0.000)	0.0006*** (0.000)
FHS adoption	−0.0860** (0.043)	−0.0240** (0.009)	0.0000 (0.000)	−0.0001 (0.000)	0.0011*** (0.000)
Population aged ≥40 years (%)	0.1807 (0.119)	−0.0127 (0.024)	0.0011*** (0.000)	0.0148*** (0.001)	0.0585*** (0.005)
Population (log)	0.1233*** (0.017)	0.0249*** (0.003)	0.0000*** (0.000)	0.0002*** (0.000)	−0.0028*** (0.000)
Municipal expenditures on health (%)	0.2522*** (0.046)	0.0423*** (0.010)	−0.0001*** (0.000)	−0.0016*** (0.000)	−0.0078*** (0.002)
Illiteracy (% of individuals aged ≥15 years)	−0.0561 (0.052)	−0.0055 (0.010)	0.0000 (0.000)	0.0003 (0.000)	−0.0028 (0.003)
Health expenditure per capita (log)	0.0341* (0.020)	0.0020 (0.004)	−0.0000*** (0.000)	−0.0006*** (0.000)	0.0021*** (0.001)
Mayor education (college or higher)	−0.0079 (0.008)	−0.0032** (0.002)	0.0000** (0.000)	−0.0000 (0.000)	−0.0003 (0.001)
Income per capita (log)	−0.0170* (0.009)	−0.0041** (0.002)	0.0000*** (0.000)	0.0001 (0.000)	0.0017*** (0.001)
Constant	−1.0621*** (0.257)	−0.0602 (0.067)	−0.0002*** (0.000)	0.0017** (0.001)	0.0097 (0.006)
N	51,257	51,134	64,665	64,496	60,283
R-squared	0.077	0.109	0.171	0.117	0.008

***$P < 0.01$; **$P < 0.05$; *$P < 0.1$.
FHS, Family Health Strategy; HiperDia, hypertension and diabetes health information system.
Robust standard errors in brackets (clusters on the municipal level).
Control variables included dummies of state, dummies of year, and their interactions.

As such, richer municipalities with better infrastructure and human capital are able to take advantage of the health system decentralization process, whereas other municipalities remain outside the process, consolidating a virtuous cycle of improvements in developed municipalities and a vicious cycle of relative deterioration in impoverished municipalities.

The effect of HiperDia is estimated according to per capita income (measured by the municipal GDP per capita) in Table 5, providing interesting results based on inequalities among municipalities within Brazilian regions. We split municipalities according to income per capita, showing a larger positive effect of HiperDia among municipalities in the richest group, the 25% of municipalities with higher income per capita. In the 25% of poorest municipalities, there are no changes or worsening results in population health outcomes.

Robustness

Estimates of Eq. (2) using IV are shown in Table 6, presenting the coefficients of the second stage of two OLS according to health indicators. The results point to a reduction in the coefficients in comparison to OLS estimates. Because we controlled for endogeneity, excluding potential bias, we had higher positive effects for indicators per prevalence and no effects for indicators per capita, indicating improvements among diabetic patients with access to health assistance because of lower mortality and hospitalization rates attributable to diabetes.

Table 4 – Difference-in-Differences estimates for diabetes outcomes indicators, according to HiperDia program adoption according to Brazilian macro regions (2000–2011).

Region	Variables	Diabetes deaths per prevalence	Diabetes hospitalizations per prevalence	Diabetes deaths per capita	Diabetes hospitalizations per capita	Diabetes prevalence per capita
Southeast	HiperDia adoption	−0.1252** (0.062)	−0.0192** (0.010)	0.00001 (0.000)	0.0005** (0.000)	0.0038** (0.002)
	N	13,829	13,828	19,580	19,588	16,723
	R-squared	0.086	0.106	0.120	0.083	0.005
South	HiperDia adoption	−0.0834* (0.050)	−0.0105 (0.012)	0.000001 (0.000)	0.00006 (0.000)	0.0014** (0.001)
	N	10,423	10,430	14,002	14,012	12,814
	R-squared	0.108	0.129	0.055	0.051	0.027
North	HiperDia adoption	0.0006 (0.008)	0.0006 (0.002)	0.00002* (0.000)	0.00017 (0.000)	0.0006 (0.000)
	N	4127	4093	5012	4954	4939
	R-squared	0.074	0.178	0.204	0.222	0.048
Northeast	HiperDia adoption	−0.0465** (0.023)	−0.00007 (0.006)	−0.00001 (0.000)	0.0003 (0.000)	0.0007 (0.000)
	N	18,799	18,736	20,615	20,537	20,505
	R-squared	0.050	0.124	0.261	0.127	0.016
Midwest	HiperDia adoption	−0.0133 (0.013)	0.0028 (0.003)	0.000001 (0.000)	0.0005 (0.000)	0.0025*** (0.001)
	N	4079	4047	5456	5405	5302
	R-squared	0.174	0.204	0.097	0.057	0.030

***P < 0.01; **P < 0.05; *P < 0.1.
FHS, Family Health Strategy; HiperDia, hypertension and diabetes health information system.
Robust standard errors in brackets (clusters on the municipal level).
Control variables included FHS adoption, population aged ≥40 years (%), population (log), municipal expenditures on health (%), health expenditure per capita (log), illiteracy (% of individuals aged ≥15 years), mayor education (college or higher), income per capita (log), dummies of state, year, and their interactions.

Table 5 – Difference-in-Differences estimates for diabetes outcomes indicators, according to HiperDia program adoption and income per capita (2000–2011).

Municipality according to income	Variables	Diabetes deaths per prevalence	Diabetes hospitalizations per prevalence	Diabetes deaths per capita	Diabetes hospitalizations per capita	Diabetes incidence per capita
25% richest	HiperDia adoption	−0.3668* (0.195)	−0.0673** (0.033)	0.0000 (0.000)	0.0001 (0.000)	0.0003 (0.001)
	N	6582	6569	9095	9092	8023
	R-squared	0.098	0.119	0.111	0.101	0.299
25% poorest	HiperDia adoption	0.0067 (0.008)	−0.0002 (0.002)	0.0000* (0.000)	0.0001 (0.000)	0.0010** (0.000)
	N	13,851	13,776	15,586	15,487	15,422
	R-squared	0.071	0.117	0.299	0.157	0.065

***P < 0.01; **P < 0.05; *P < 0.1.
FHS, Family Health Strategy; HiperDia, hypertension and diabetes health information system.
Robust standard errors in brackets (clusters on the municipal level).
Control variables included FHS adoption, Population aged ≥40 years (%), Population (log), Municipal expenditures on health (%), Health expenditure per capita (log), Illiteracy (% of individuals aged ≥15 years), Mayor education (college or higher), Income per capita (log), dummies of state, year, and their interactions.

Table 6 – Difference-in-Differences: instrumental variable second stage estimates for diabetes outcomes indicators.

Variables	Diabetes deaths per prevalence	Diabetes hospitalizations per prevalence	Diabetes deaths per capita	Diabetes hospitalizations per capita	Diabetes prevalence per capita
HiperDia adoption	−0.2090** (0.098)	−0.0532** (0.021)	0.0000** (0.000)	0.0000 (0.000)	0.0038*** (0.001)
N	50,758	50,635	64,001	63,832	59,669
R-squared	0.100	0.056	0.170	0.115	0.007

***P < 0.01; **P < 0.05; *P < 0.1.
FHS, Family Health Strategy; HiperDia, hypertension and diabetes health information system.
Robust standard errors in brackets (clusters on the municipal level).
Control variables included FHS adoption, population aged ≥40 years (%), population (log), municipal expenditures on health (%), health expenditure per capita (log), illiteracy (% of individuals aged ≥15 years), mayor education (college or higher), income per capita (log), dummies of state, year, and their interactions.

Discussion

Recently, there has been a worrying trend in national health systems management, namely deviating government efforts from primary health care either due to excessive fragmentation of healthcare delivery or intense focus on specialization, curative care, and short-range health outcomes.[31]

The major goals of health systems encompass improvements in population health status and health outcomes under reasonable financing schemes to protect against financial risks. Thus, primary healthcare programs can contribute significantly to advances in health outcomes through NCD prevention and control, particularly in diabetes management, reducing costs due to comorbidities and complications.[2,26]

Accordingly, the Brazilian FHS seeks to promote improvements in regular access and follow-up of patients with primary healthcare providers to guarantee supply of medication and inputs and also to incentivize disease monitoring and control, behavior changes, and health promotion through multidisciplinary health professional team support. The strategy seeks to improve alignment of local and national health administrations with other social groups toward common goals for the national health system.[23]

The evidence shown in this study illustrated the impact of decentralization of primary health care on NCD outcomes in Brazil. However, it should be pointed out that exposure and access to primary health care may contribute to NCD prevention and control to a certain extent, especially in view of the following health strategies: facilitation of patient self-management through continuous support and communication; adoption of information and communication technology to track patient records; provision of quality and targeted health care; and establishment of health service networks throughout the national health system to enable access to diagnosis and admission to medium- and high-complexity health care.[2]

There is limited evidence on primary healthcare programs directed toward NCD therapeutic management in the context of decentralization with universal healthcare coverage in highly populated developing countries, such as described here. Thus, results of this study are important because of their contribution to the design of NCD prevention strategies for decentralized health programs in the context of developing countries trapped on the midst of incomplete epidemiologic transition, like Brazil.[9]

Considering the limited resources of health system, it is important to seek preventive approaches within low-cost primary healthcare settings. In addition, the role of the Brazilian federal government in granting incentives for local governments toward the minimization of population exposure to NCD risk factors and the resolution of basic sanitation problems linked with contagious infectious diseases may lead to significant improvements in health conditions for its population.

The heterogeneous impact of HiperDia in diabetes indicators, where decentralization improves only the best municipalities, may be explained by differences in infrastructure and human capital in diverse regions.[20] Our hypothesis is that there is a lack of proper access to health systems and treatment of patients in smaller and poorer municipalities located in remote regions. Our basis for this is four-fold. First, municipalities may want to split into other municipalities because of the financial incentives posed by the central government. There is a fixed part of federal transfers for health system maintenance, especially for primary health care, which generates significant revenue at the local level, hence motivating the split into more than one municipality.

Second, there are no minimum requirements regarding presentation of previous planning or programming to create new municipalities in Brazil. In addition, the process is usually based on political interests followed by bureaucracy, without assurance of sufficient investments in infrastructure, human capital, or governance. Approximately, 60 new municipalities were created between 2000 and 2010 (the period of our analysis), but these were not included in our sample.

Third, it is difficult to maintain physicians and other health professionals working in distant locations, especially in rural areas away from the largest metropolitan regions, because of opportunity costs in Brazil. In 2009, there were 3.7 physicians per 1000 inhabitants in the Southeast and South, the richest regions in Brazil, compared with 1.9 per 1000 inhabitants in the North, which is the poorest region (see Table A1 in the Appendix). It is important to highlight that the FHS program was designed to correct the inequalities in distribution of health professionals within Brazilian regions and states, thus providing access to remote populations (i.e. the distribution of physicians in remote areas in 2009 was improved compared with the scenario prior to the creation of the FHS in 1996).

Finally, educational attainment may be a factor for the success of the healthcare system. The poorest regions have a higher rate of illiteracy, 15% in the Northeast, while illiteracy is only 3.7% in the richest Southeast region (see Table A1 in the Appendix), which may contribute to the differences seen in diabetes indicators in these regions.

Conclusions

Taking advantage of the HiperDia program design and implementation (an information system with staggered adoption by Brazilian municipalities), we performed an analysis on the health system decentralization process based on municipal diabetes indicators. Our results indicate (i) a significant increase of population access to the health system, revealed by the significant increase in diabetes prevalence throughout the decade and by diabetes indicators in per capita terms; (ii) an improvement in mortality rates and hospitalizations per prevalence as a result of HiperDia adoption, with and without controls for endogeneity; and (iii) heterogeneous results related to income and development levels of the municipality.

Overall, the HiperDia program was successful in reaching the target population and improving mortality and morbidity rates; consequently, the decentralization process positively impacted diabetes indicators in Brazilian municipalities. Our results, however, point to greater improvements in the richest regions and approximately null effects in the poorest regions, similar to previous literature findings. In terms of diabetes, healthcare decentralization only had a positive effect in the richest areas, which are connected to better infrastructure and available human capital.

The main data limitation of this study referred to the level of information according to municipality. In general, studies of diabetes are conducted using individual-level databases. Thus, the panel data used in this study created some difficulties in the use of controls for diabetes incidence (e.g. obesity prevalence).

Author statements

Ethical approval

The research is exempt from ethical approval because of the utilization of secondary data sets with aggregated data at the municipal level in Brazil, covered by legislation allowing such utilization for research purposes.

Funding

The study was performed with funding from the São Paulo Research Foundation (FAPESP).

Competing interests

The authors of the study declare that there are no competing interests involved in the design, analysis, and publication of the manuscript.

REFERENCES

1. Kenkel DS. Prevention. In: Culyer AJ, Newhouse JP, editors. *Handbook of health economics*, vol. 1(B). New York: Elsevier; 2000. p. 1675–720.
2. Macinko J, Dourado I, Guanais FC. Chronic diseases, primary care and health systems performance: diagnostics, tools and interventions. Discussion paper (2011) IDB-DP-189. Washington, D.C.: Inter-American Development Bank.
3. Kremer M, Glennerster R. Improving health in developing countries: evidence from randomized evaluations. In: Culyer AJ, Newhouse JP, editors. *Handbook of health economics*, vol. 2. New York: Elsevier; 2011. p. 201–315.
4. Alwan A. *Global status report on noncommunicable diseases 2010*. Geneva: World Health Organization; 2011.
5. American Diabetes Association. Diagnosis and classification of diabetes mellitus. *Diabetes Care* 2014;**37**(1):S81–90.
6. Lozano R, Naghavi M, Foreman K, Lim S, Shibuya K, Aboyans V. Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2013;**380**(9859):2095–128.
7. Bommer C, Sagalova V, Heesemann E, Manne-Goehler J, Atun R, Bärnighausen T, et al. Global economic burden of diabetes in adults: projections from 2015 to 2030. *Diabetes Care* 2018;**41**(5):963–70. https://doi.org/10.2337/dc17-1962.
8. Schmidt MI, Duncan BB, Silva GA, Menezes AM, Monteiro CA, Barreto SM, et al. Chronic noncommunicable diseases in Brazil: burden and current challenges. *Lancet* 2011;**377**(9781):1949–61.
9. Almeida G, Sarti FM, Ferreira FF, Diaz MDM, Campino ACC. Analysis of the evolution and determinants of income-related inequalities in the Brazilian health system, 1998-2008. *Pan Am J Public Health* 2013;**33**(2):90–7.
10. Gragnolati M, Lindelow M, Couttolenc B. *Twenty years of health system reform in Brazil: an assessment of the Sistema Único de Saúde*. Washington, DC: World Bank; 2013.
11. Dmytraczenko T, Torres FM, Aten A. Universal health coverage policies in Latin America and the Caribbean. In: Dmytraczenko T, Almeida G, editors. *Toward universal health coverage and equity in Latin America and the Caribbean: evidence from selected countries*. Washington, DC: World Bank; 2015.
12. Aquino R, Oliveira NF, Barreto ML. Impact of the family health program on infant mortality in brazilian municipalities. *Am J Public Health* 2010;**99**(1):87–93.
13. Guanais FC, Macinko J. The health effects of decentralizing primary care in Brazil. *Health Aff* 2009;**28**(4):1127–35.
14. Macinko J, Almeida C, De Sá PK. A rapid assessment methodology for the evaluation of primary care organization and performance in Brazil. *Health policy and planning, London* 2007;**22**(3):167–77.
15. Rocha FF, Nishijima M, Peixoto SGD. Primary healthcare policies: investigation on morbidity. *Appl Econ Lett* 2013;**20**(11):1046–51.
16. Wagstaff A, Dmytraczenko T, Almeida G, Buisman L, Eozenou PH-V, Bredenkamp C, Cercone JA, Diaz Y, Maceira D, Molina S, Paraje G, Ruiz F, Sarti F, Scott J, Valdivia M, Werneck H. Assessing Latin America's progress toward achieving universal health coverage. *Health Aff* 2015;**34**(10):1704–12.
17. Tiebout CM. A pure theory of local expenditures. *J Polit Econ* 1956;**64**(5):416–24.
18. Musgrave RA. *The theory of public finance*. New York: McGraw-Hill; 1959. p. 161–385.
19. Bolton P, Farrell J. Decentralization, duplication, and delay. *J Polit Econ* 1990;**98**(4):803–26.
20. Galiani S, Gertler P, Schargrodsky E. Water for life: the impact of the privatization of water services on child mortality. *J Polit Econ* 2005;**113**(1):83–120.
21. Bardhan P. Decentralization of governance and development. *J Econ Perspect* 2002;**16**(4):185–205.
22. Oates WE. An essay on fiscal federalism. *J Econ Lit* 1999;**37**(3):1120–49.
23. Jakubowski E, Saltman RB. *The changing national role in health system governance: a case-based study of 11 European countries and Australia*. Geneva: World Health Organization; 2013.
24. Costa-Font J, Greer SL, editors. *Federalism and decentralization in European health and social care*. Basingstoke: Palgrave Macmillan; 2013.
25. Bossert TJ. *Decentralization and governance in health. Policy brief health systems 20/20*. Washington, D.C.: U.S. Agency for International Development; 2008.
26. Brinkerhoff DW, Bossert TJ. Health governance: principal-agent linkages and health system strengthening. *Health Pol Plann* 2014;**29**:685–93.
27. Diaz-Serrano L, Rodríguez-Pose A. Decentralization and the welfare state: What do citizens perceive? *MPRA paper 54123*. Munich: Munich University Library; 2014.
28. Avelino G, Barberia LG, Biderman C. Governance in managing public health resources in Brazilian municipalities. *Health Pol Plann* 2014;**29**(6):694–702.
29. Wickremasinghe D, Hashmi IE, Schellenberg J, Avan BI. District decision-making for health in low-income settings: a systematic literature review. *Health Pol Plann* 2016;**31**:ii12–24.
30. Wooldridge JM. *Econometric analysis of cross section and panel data*. Cambridge, MA: MIT Press; 2002.
31. World Health Organization (WHO). *Primary healthcare: now more than ever. World health report* 2008. Geneva: World Health Organization; 2008.

Appendix 1

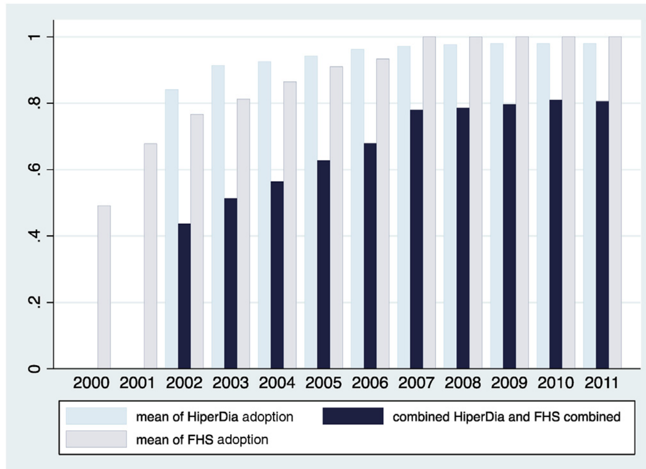

Fig. A1 – Evolution of HiperDia adoption, FHS, and its combination variable (2000–2011). Source: DATASUS, Brazilian Ministry of Health. FHS, Family Health Strategy; HiperDia, hypertension and diabetes health information system.

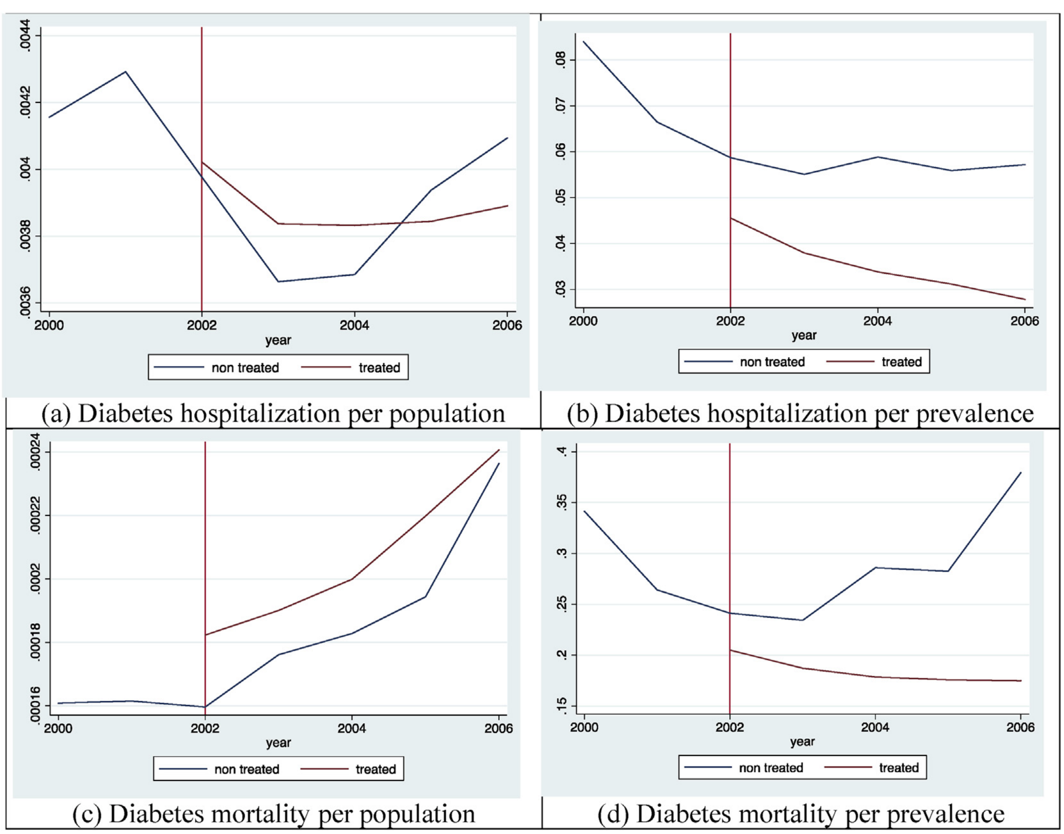

Fig. A2 – Trends of diabetes indicators according to treatment groups (2000–2006).

Table A1 – Physicians per 1000 inhabitants and rate of illiteracy, according to Brazil's regions and states

Region/state	Physicians per 1000 inhabitants (2009)	Rate (%) of illiteracy in adults aged >15 y (2010)
North	1.9	8.1
Rondônia	1.8	7.5
Acre	2.3	12.7
Amazonas	2.3	5.0
Roraima	2.6	5.0
Pará	1.5	9.8
Amapá	2.4	1.5
Tocantins	2.2	9.2
Northeast	2.4	15.0
Maranhão	1.3	14.9
Piauí	2.3	19.2
Ceará	2.2	14.9
Rio Grande do Norte	3	14.7
Paraíba	2.7	18.0
Pernambuco	2.4	14.2
Alagoas	2.7	20.8
Sergipe	4.2	14.1
Bahia	2.3	13.0
Southeast	3.7	3.7
Minas Gerais	3.9	5.7
Espírito Santo	3.6	6.0
Rio de Janeiro	3.2	2.8
São Paulo	3.9	3.0
South	3.7	3.7
Paraná	3.4	4.6
Santa Catarina	3.7	3.3
Rio Grande do Sul	4.1	3.1
Midwest	2.9	5.5
Mato Grosso do Sul	3.5	6.2
Mato Grosso	2.3	7.3
Goiás	3	5.6
Distrito Federal	2.8	2.5
Brazil	3.1	9.7

Source: DATASUS and IBGE.