Université de Montréal

"Health Capabilities, Public Policies and the Determinants of Infant Mortality in Brazil"

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Thèse présentée en vue de l'obtention du grade de *Philosophiae Doctor* - *PhD*
Doctorat en santé publique, option Organisation des soins de santé

Décembre 2020

Université de Montréal
École de Santé Publique
Département de gestion, d'évaluation et de politique de santé

Cette thèse intitulée

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Résumé

Le taux de mortalité infantile est un indicateur de santé des populations et de l'efficacité des systèmes de santé. Il est également capable d'estimer l'ampleur des inégalités sociales et en matière de santé entre populations. Au cours des 30 dernières années, le Brésil a enregistré des réductions significatives des taux de mortalité infantile. Entre 1990 et 2017, le taux de mortalité des moins de cinq ans est passé de 53,7 décès pour mille naissances vivantes à 15,6. Une réduction de 71% sur la période. La moyenne nationale de réduction était de 6% par an dans les années 90, passant à 4,8% dans les années 2000 et à 3,2% par an entre 2011 et 2015. De nombreux facteurs ont été signalés comme la cause de ces améliorations.

Malgré la mise en œuvre de politiques sociales et de santé qui ont eu un impact positif sur la santé des populations brésiliennes au cours des dernières décennies, depuis 2009 le pays a connu une lente diminution de la baisse de la mortalité infantile qui est restée à des niveaux élevés, enregistrant de grandes disparités régionales. Après une crise économique qui a évolué vers une période troublée de crise politique, le pays a enregistré en 2016 une augmentation de la mortalité infantile chez les moins d'un an et de cinq ans, qui est passé de 12,43 à 12,72 décès pour mille naissances vivantes et de 14,28 décès à 14,89 décès pour mille naissances vivantes, respectivement.

Ces éléments attirent l'attention sur l'impact possible des déterminants sociaux de la santé sur les taux de mortalité infantile au Brésil après la mise en œuvre de ces politiques sociales et de santé. Cette anomalie observée dans la tendance de la mortalité infantile, combinée aux disparités régionales et à une lente diminution de la baisse des taux de mortalité infantile est préoccupante. Elle soulève des questions sur l'impact de ces politiques sociales et de santé, sur la capacité du pays à maintenir une réduction du taux de mortalité infantile à long terme, et sa capacité à rejoindre les taux des pays développés, ainsi quels sont les déterminants de la mortalité infantile au Brésil après la mise en œuvre de ces politiques publiques?

L'objectif premier de cette thèse était d'identifier les déterminants de la mortalité infantile au Brésil après la mise en œuvre du programme Stratégie Santé Famille et du Programme *Bolsa Família* afin de formuler des hypothèses plausibles, relatives au ralentissement du taux de mortalité chez les moins d'un an et de cinq ans, aux disparités régionales et à l'anomalie observée dans la tendance à la baisse du taux de mortalité infantile au Brésil. Pour atteindre cet objectif, nous avons effectué

trois études: 1) un examen de la portée qui visait à identifier et à résumer les déterminants de la mortalité infantile au Brésil sous l'influence de ces programmes, en vue de formuler des hypothèses relativement à l'évolution récente des taux de mortalité infantile au Brésil et d'identifier les lacunes, en termes de recherche, concernant les déterminants de la mortalité infantile dans le pays; 2) une analyse descriptive rétrospective, dans une optique de santé publique et des inégalités en matière de santé, en adoptant le cadre analytique proposé par la Commission de l'OMS sur les déterminants sociaux de la santé, en utilisant les données du taux de mortalité chez les enfants de moins d'un an et des possibles déterminants de la mortalité infantile au Brésil selon les conclusions de notre examen de la portée (article 1); 3) une proposition de méthodologie pour faire face aux défis liés au développement d'un modèle de données de panel en utilisant des données agrégées des 26 états brésiliens et des différentes sous-régions, selon le « Conceptual Model of Health Capability » , afin d'inférer des associations possibles entre nos variables indépendantes et les taux de mortalité infantile au Brésil et pour vérifier l'hypothèse soulevée dans l'examen de cadrage sur les récents changements des indicateurs de mortalité infantile du pays.

Les résultats globaux de ces études ont démontré qu'à la lumière du « Conceptual Model of Health Capability » et des déterminants sociaux de la santé, les disparités régionales liées aux inégalités, notamment aux niveaux du revenu, de l'éducation, de l'emploi, du taux de fécondité, de l'accès et de la qualité des services de santé, expliquent les inégalités en termes de taux de mortalité infantile, en particulier dans les macro-régions du nord et du nord-est du pays, ce qui freine probablement la baisse du taux de mortalité infantile. Ces inégalités expliqueraient à la fois la lenteur de la réduction du taux de mortalité infantile et sa tendance à demeurer à des niveaux relativement élevés. Les résultats ont également montré que les variations de ces facteurs, pour des raisons liées à la crise économique et politique, ont probablement perturbé la tendance à la baisse des taux de mortalité infantile. À cet égard, les résultats suggèrent qu'une forte réduction du taux d'emploi, observée entre 2014 et 2015 entre autres facteurs, pourrait avoir eu un impact différé sur le TMI en 2016. Les résultats ont également permis d'établir une association entre l'emploi et différents indicateurs de mortalité infantile, le taux d'emploi pouvant avoir un impact sur la mortalité infantile jusqu'à trois ans. Enfin, les études ont démontré qu'il existe un seuil de revenu des ménages, qui agit comme facteur de protection contre la mortalité infantile, en dessous duquel plus la proportion de ménages est élevée, plus le risque d'augmentation de la mortalité infantile est élevé.

Mots-clés : Mortalité infantile, capabilités en santé, approche des capabilités, politiques publiques, déterminants sociaux de la santé, programme de transfert conditionnels en espèces, Programme *Bolsa Família*, données de panel à plusieurs niveaux à effets fixe nichés en grappes, économie de la santé, Brésil

Abstract

The infant mortality rate is an indicator of population health and the effectiveness of health systems that is also capable of estimating the extent of social and health inequalities between populations. Over the last 30 years, Brazil has recorded significant reductions in child mortality rates. Between 1990 and 2017, the under-five mortality rate dropped from 53.7 to 15.6 deaths per thousand live births, a 71% reduction over the period. The national reduction average was 6% per year in the 1990s, decreasing to 4.8% in the 2000s and to 3.2% per year between 2011 and 2015, and many factors have been reported as the cause of these improvements.

Even after the implementation of health and social policies that positively affected the health of the populations in Brazil in the last decades, since 2009 the country has experienced a slow decrease in the decline in infant mortality that remained at high levels, registering great regional disparities. After an economic crisis that evolved into a troubled period of political crisis, in 2016 the country recorded increases in under-one-year infant mortality and under-five-year infant mortality rates, that raised from 12.43 deaths to 12.72 deaths per thousand live births and from 14.28 deaths to 14.89 deaths per thousand live births, respectively.

These facts call attention to the possible impact of social determinants of health on infant mortality rates in Brazil after the implementation of these health and social policies.

This anomaly in the trend of child mortality, particularly when combined with regional disparities and a slow decrease in the decline in infant mortality rates is of great concern and raise questions about what is the extent of these health and social policies on the country's ability to maintain a longer-term decline in the infant mortality rate, is it capable of placing this rate at the level of developed countries and what are the determinants of infant mortality in Brazil after the implementation of these public policies.

The overarching goal of this thesis was to identify the determinants of infant mortality in Brazil after the implementation of the Family Health Strategy and the *Bolsa Família* programs in order to raise plausible hypotheses for the slowdown, the regional disparities, and the anomaly observed in the trend of declines in the infant mortality rate in Brazil. To attain this objective, we conducted three research papers: 1. a scoping review that aimed at identifying and summarizing the determinants of infant mortality in Brazil under the influence of Family Health Strategy and *Bolsa Família* programs, with a view of raising hypothesis for the recent changes in the infant mortality rates in Brazil and identifying gaps in terms of research concerning the determinants of infant

mortality in the country, 2. a descriptive retrospective analysis according to the perspective of Public Health and health inequalities by adopting the analytical framework proposed by the World Health Organization's Commission on Social Determinants of Health, using data from under-one-year old infant mortality rate and from possible determinants of infant mortality in Brazil according to the findings of our scoping review (article 1), and 3. a methodological proposal in order to overcome the challenges to developing a panel data model using aggregated data from the 26 Brazilian states and different subregions according to the Conceptual Model of Health Capability, with a view of inferring possible associations between our independent variables and infant mortality rates in Brazil, aiming at reviewing the hypothesis raised in the scoping review about the recent changes in the country's infant mortality indicators.

The global results of these studies demonstrated that in the light of the Conceptual Model of Health Capability and the social determinants of health, regional disparities related to inequalities in factors such as income, education, employment, fertility rate, access, and quality of health services, account for inequalities in infant mortality rates, especially in the north and Northeast macro-regions of the country, which likely hamper further reductions of infant mortality. Those inequalities would explain both the slowdown in the reduction and the tendency of the infant mortality rate to remain at relatively high levels. Results also demonstrated that variations in those factors for reasons relating to the economic and political crisis, likely have interrupted the secular trend of declining infant mortality rates. In this regard, results suggest that a sharp reduction in employment rate observed between 2014 and 2015, among other factors, may have had a delayed impact on infant mortality rates in 2016. The results also identified an association between employment and different infant mortality indicators, with employment rate possibly impacting child mortality up to three years. Finally, the studies have shown that a household income threshold acts as a protective factor against child mortality, the bigger the proportion of households below this income bracket, the greater the risk of an increase in child mortality.

Keywords: Infant mortality, health capabilities, capabilities approach, public policies, social determinants of health, conditional cash transfer program, *Bolsa Família*, Multilevel panel data with fixed effect nested within-cluster, Health Economics, Brazil

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Literature review

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List of abbreviations

BFP: *Bolsa Família* Program

CCT: Conditional Cash Transfer Program

CMHC: Conceptual Model of Health Capability

DATASUS: Brazilian Health Ministry database

ENMR: Early neonatal mortality rate

FDI: Family Development Index

FHS: Family Health Strategy

HDI: Human Development Index

IBGE: Brazilian Institute of Geography and Statistics

IMR: Infant mortality rate

LBW: Low birth weight

LBWP: Low Birth Weight Paradox

LILACS: Latin American and Caribbean Literature in Health Sciences

LNMR: Late neonatal mortality rate

MEDLINE:US National Library of Medicine

MeSH: Medical Subject Headings database descriptors

MHDI: Municipal Human Development Index

MMAT: Mixed Methods Appraisal Tool

NMR: Neonatal mortality rate

PMAQ: National Program for Improving Access and Quality of Primary Care

PMR: Perinatal Mortality Rate

PNAD: National Household Sample Survey

PNMR: Post neonatal mortality

SciELO: Scientific Electronic Library Online

SDH: Social Determinants of Health

SUS: *Sistema Único de Saúde*

UNEP: United Nations Environment Program/ World Health Organization – WHO

WHO: World Health Organization

The identity of an individual is essentially a function of his or her choices,
rather than the discovery of an immutable attribute.
Amartya Sen

The main force pushing toward reduction in inequality has always been
the diffusion of knowledge and the diffusion of education.
Thomas Piketty

Knowledge is not a guarantee of good political behavior,
but ignorance is a virtual guarantee of bad behavior.
Martha Nussbaum

Acknowledgements

First and foremost, I would like to thank all my family for their patience and for supporting me unconditionally.

I also would like to express my sincere gratitude to my supervisors, Dr. Roxane Borgès Da Silva, Dr. Claude Sicotte and Dr. Ladislau Dowbor, who had immensely contributed to this fruitful journey through knowledge.

The Ph.D. journey is not an easy one, but indeed, it has been the most inspiring and challenging period of my life so far. Without the great professors and colleagues who inspired and encouraged me during my time studying at ESPUM, it would be meaningless to get through it.

Statement of financial support

During the first two years in the PhD program in Public Health at the École de Santé Publique de l'Université de Montréal (ESPUM), I received financial support from CAPES Foundation (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, Ministry of Education of Brazil, Brasilia – DF 700040-020, Brazil – Science without Borders Program – proc. 12940/13-5). In 2017, for the last winter scholar session, I received financial support by FESP (Faculté d'Études Supérieures – ESPUM – École de Santé Publique de l'Université de Montréal).

Chapter 1 Introduction

The context of infant mortality in Brazil

The infant mortality rates are indicators of population health and the effectiveness of health systems that are also useful for estimating the extent of social and health inequalities between populations (Reidpath 2003; Laurenti 1996; Duarte 2007).

The causes of child mortality

At the Global level, in 2010 the main causes of neonatal deaths (from birth to the 27th day of life) were due to infectious diseases, complications related to preterm birth, and intrapartum problems, while pneumonia, diarrhea and malaria accounted for the majority of deaths in older children (Liu et al. 2012). In 2015, neonatal mortality represented approximately 46% of all child mortality (deaths from birth to 5 years of age) (Liu et al. 2016). The overall Global trend points to reductions in mortality from pneumonia, diarrhea, neonatal intrapartum events, malaria, and measles and were responsible for 61% of the total reduction in under-five mortality between 2000 and 2015. Although there is a global trend of change in cause of death of child mortality, there is no evidence of a homogeneous epidemiological transition. Cause of death distribution varies across regions, countries, and at sub-national levels. In developing countries with very high under-five mortality, communicable diseases are among the three leading causes, whereas among the countries with very low mortality rates the three leading causes are all non-communicable diseases (Liu et al. 2015; Liu et al. 2016; Liu et al. 2016-II).

India holds the highest number of under-five mortality in the world in 2015 (1,2 million), with significant subnational disparities. This high level of under-five mortality reflects the also elevated number of live births (25,121 million). At the subnational level, cause-specific of deaths are unevenly distributed between states, with infectious diseases such as pneumonia and diarrhea among the three leading causes-of-death in states with higher under-five mortality, and preterm birth complications, and intra-partum problems among the three leading causes in states with lower under-five mortality. 57.9% of all those deaths occurred in the first 28 days of life (Liu et al. 2019).

In China, from 2009 to 2015 under-five mortality have declined by 37.1%. The leading causes of death in 2015 were preterm birth complications, birth asphyxia, and congenital abnormalities. The cause of deaths varied enormously across Chinese provinces with different development levels. The leading cause of death of under-five mortality in provinces with lower under-five mortality was congenital abnormalities, while in the provinces with higher under-five mortality, pneumonia was the predominant cause of death (Song et al. 2016).

In 2015, in Latin America and Caribbean countries, neonatal deaths accounted for 51.5% of total under-five mortality and had among the three leading causes-of-deaths complications related to preterm birth and intra-partum related events (Liu et al. 2016-II).

The causes of child mortality in Brazil

Under-five deaths in Brazil counted 191,505 in 1990 and 51,226 in 2015, and 90% of these deaths occurred during the first year of life. There is a change in the proportion of deaths by age between that interval. In 1990, the highest proportion of deaths was concentrated in the post-neonatal period (28-364 days), accounting for 44% of under-five deaths. In 2015, early neonatal mortality (0–6 days) was the main component of child mortality, representing for 41% of total deaths. Despite a 72% decrease in preterm birth between 1990 and 2015, preterm complications appear as one of the three main cause of deaths in both years, followed by diarrheal diseases and lower respiratory infections in 1990, and congenital anomalies, asphyxia, and trauma at birth in 2015. Between 1990 and 2015 diarrheal diseases dropped from the second cause of death to the seventh. On the other hand, congenital anomalies were the fifth most important cause of under-five mortality in 1990, and became the second leading cause in 2015 (França et al. 2017).

Over the last 30 years, Brazil has recorded significant reductions in child mortality rates. Between 1990 and 2017, the under-five mortality rate (U5MR) dropped from 53.7 deaths per thousand live births to 15.6, a 71% reduction over the period. The national reduction average was 6% per year in the 1990s, decreasing to 4.8% in the 2000s and to 3.2% per year between 2011 and 2015 which allowed the country to achieve the target proposed by the Millennium Development Goals (MDGs) (UNICEF 2019).

The changing of the cause of deaths in child mortality, the transition observed in the proportion of deaths by age, and the reduction of child mortality rates are largely the result of the implementation of public policies during the last decades.

Public policies in Brazil

A new Constitution enacted in 1988 has established the right to health as a universal human right and an obligation of the State. The Constitution laid the grounds for the implementation of the SUS - *Sistema Único de Saúde* (Unified Health System). The main objectives of the SUS were: universality, equity, integrality, decentralization, hierarchization and community participation.

In 1994, The Ministry of Health created the Family Health Program (now operating under the name of Family Health Strategy (FHS)). The FHS was a decentralized program based on

community healthcare. Before the implementation of the FHS, public healthcare was based on a hospital-centered model and the assistance provided to the population focused on medium-high complexity sectors, causing a greater demand for resources and low resolution (Gomes et al. 2016). The supply of basic health care at the community level renewed the definition and the form of health-care provision in Brazil. The rationale behind the program is the prevention and provision of basic health through the action of professional healthcare teams directly intervening at the community level (Rocha and Soares 2010). Each FHS team was composed of at least one doctor, a graduated nurse, a nursing assistant and 4 to 6 community health agents (Rasella, Aquino, and Barreto 2010a) which were responsible for a continuous follow-up of a given number of families residing in a specific area and for establishing ties of commitment and shared responsibility. The interventions included promotion, prevention, and care for mothers and children, such as the promotion of breastfeeding, prenatal care, neonatal and under-five care, immunization and other actions toward prevention, and management of infectious diseases such as diarrhea and pneumonia (Aquino, de Oliveira, and Barreto 2009).

The program was developed based on the principles of primary care established by the Alma-Ata convention with the focus on the individual and not only on the disease (Rasella, Aquino, and Barreto 2010b; WHO 1978). The FHS was the gateway to the SUS and used the support provided by the community health team as a hub for services provided by the partners of the public health system, in order to guarantee universality and comprehensiveness of health care (WHO 2008).

There are some specific pathways through which primary care can result in lower infant mortality during both neonatal and post-neonatal (deaths between 28 and 364 days of life) periods. Neonatal deaths are associated with quality prenatal care, which allows early identification and actions aiming at minimizing the damages to child health (Barbosa 2014). The quality of prenatal care is influenced by the access to health care facilities, the numbers of prenatal consultations, and qualified health workers (Russo et al. 2019). There are two pathways through which primary care may decrease post-neonatal mortality. Firstly, primary care combines interventions to improve maternal and infant health, and better management of conditions affecting the post-neonatal period, including the identification and treatment of infectious diseases and safety guidelines. Second, primary care address a series of maternal risk factors related to infant deaths, such as smoking, alcoholism, poor weight gain during pregnancy, sexually transmitted diseases and poor nutrition. (Russo et al. 2019; Shi et al. 2004).

Those pathways from which the FHS can improve maternal and child health highlight the fact that the program had a priority on the intermediate determinants of infant mortality such as maternal reproductive history, behavior such as smoking and alcohol consumption, prenatal care such as the number of consultations, type of childbirth, access to services and childbirth assistance, immunization, environment and safety, and proximal determinants of infant mortality such as maternal age, type of pregnancy, prematurity, birth weight and malformation, (Lansky et al. 2014; Barbosa 2014).

In 2019, according to data from the Ministry of Health, 43,190 FHS teams were working in Brazil, allocated in 98.4% of the 5,570 municipalities, serving approximately 64% of the Brazilian population, or 133 million people. Primary health care as a whole serves 74% of the population, which corresponds to 154 million people. The number of teams has grown systematically since 2007, when it had 24,173 teams, covering about 42% of the Brazilian population. Regarding territorial expansion, in the first ten years, the FHS had a strong expansion in Brazilian municipalities and in 2004 it covered 88% of them (Ceccon et al. 2014; Manitto M.M.; Chiesa 2019; Macinko 2020).

Despite the improvements associated with the expansion and reorganization of health services, income inequality in Brazil is among the highest in the world and major inequalities of health status across socioeconomic levels are widespread and low-income families are likely to experience stronger barriers to access to health care services (Guanais 2013).

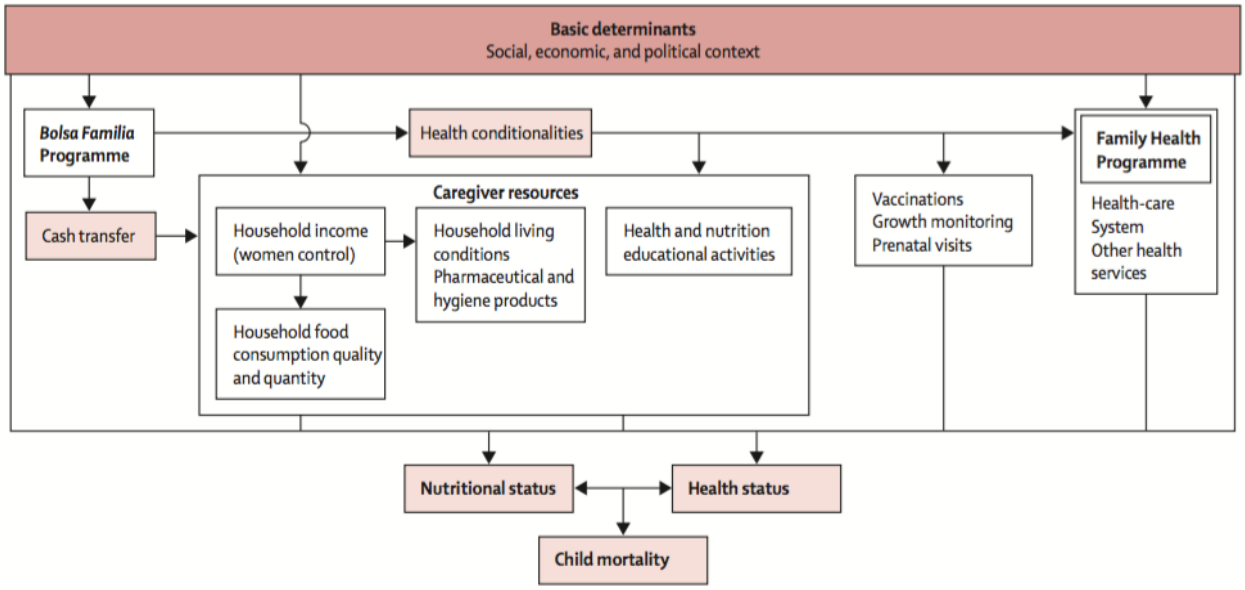
Conditional cash transfer programs CCT are interventions that transfer money from governments to poor families on the condition that parents comply with specific conditions (conditionalities), usually with a focus on the health and education of their children. Cash transfer aims to promptly alleviate poverty and conditionalities encourage the use of existing health and education services. The first CCTs were implemented in the late 1990s in Mexico (*Oportunidades* Program, former *Progresa* Program) and Brazil (PBF, former *Bolsa Escola* Program), spreading rapidly to several countries worldwide, making it is an important strategy for poverty alleviation and reduction of inequalities in low and middle-income countries. The conditionalities required for families' access to the direct benefits of these programs (cash payments) vary according to the format of the different versions implemented globally (Rasella et al. 2013; Handa and Davis 2006).

The Brazilian CCT, *Bolsa Família* Program (BFP), was established in 2003 to ensure access to health and education for families living in poverty and extreme poverty, aiming to reduce poverty

and income inequities. The program unified several existing programs: School Grant, Food Grant, Food Card, and Gas Grant (de Andrade et al. 2015). BFP provided monthly cash transfers to poor families on the condition that they meet the program's health and educational conditionalities. Cash transfers were made preferentially to women through credits to beneficiaries' electronic cards. The health conditionalities of the program established that parents were required to ensure that children younger than seven years of age had to comply with a routine of check-ups and growth monitoring and a childhood vaccination program. Pregnant women and nursing mothers were expected to be engaged in care and nutritional education programs in their local healthcare provider. The educational conditionalities stipulated that children aged 6–17 years had to be enrolled in school and maintain a minimum attendance rate according to their age bracket (Shei 2013). The requirements for participation in the program were uniform across the country and depended on household per capita income and the number and age of family members. The maximum household per capita income for eligibility was approximately US$70.25 per month (Guanais 2013).

The logic pathway through which BFP can affect child mortality is described below (Figure 1) in a framework developed by Rasella *et al.* (Rasella et al. 2013).

Figure 1 Mechanisms linking the *Bolsa Família* Program to child nutrition and health outcomes



According to Rasella *et al.*, like other CCT's, BFP can affect child survival through different mechanisms (figure 1), largely focused on income improvement and health conditions. An increased income can increase access to food and other health-related goods, and health-related conditionalities can improve access to health services. In this sense, once the BFP can improve

socioeconomic conditions that effects inequalities in the access to health care, food consumption, and pharmaceuticals, operating complementarily to FHS, impacting also the distal determinants of health (socioeconomic determinants) that may hamper the use of health services system that affect individual conditions (Rasella et al. 2013; Shei 2013).

Since the implementation of the SUS and the creation of both programs, overall health indicators have improved, and progress has been made in reducing inequalities across the country. Over the last 30 years, there has been an increase in life expectancy, a drop in maternal and infant mortality, and a sharp decline in mortality due to transmissible diseases, among other improvements that were observed (Souza et al. 2018). The association between the expansion of both BFP and FHS with reductions in child mortality, especially in infant mortality rate (IMR), the post-neonatal mortality rate (PNMR), and under-five-years mortality rates (U5MR) are well documented (Rasella et al. 2013; Guanais 2013; Vieira-Meyer et al. 2019).

Statement of problem

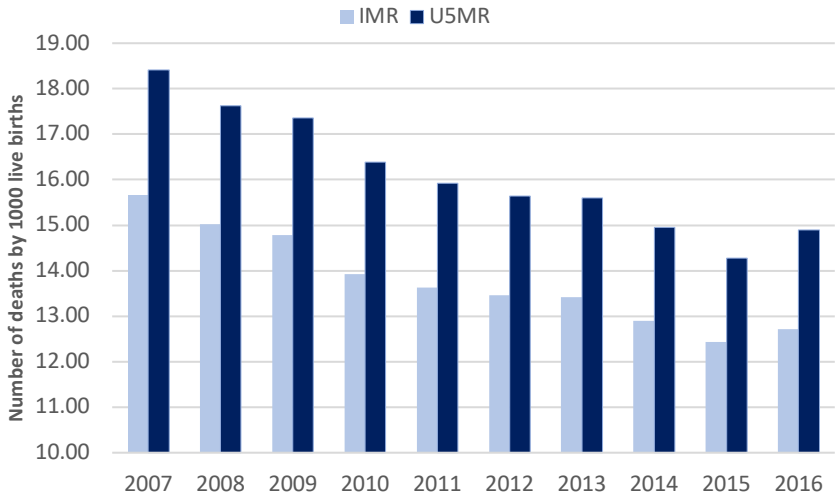
Despite the implementation of health and social policies that positively affected the health of the populations in Brazil in the last decades, since 2009 the country has experienced a slow decrease in the decline in infant mortality (Observatório de Saúde da RMSP 2018) that remained at high levels, registering great regional disparities (UNICEF 2015). In addition, after an economic crisis that evolved into a troubled period of political crisis, in 2016 the country recorded increases in infant mortality rates.

Although the global financial crisis of 2008 barely affected the Brazilian economy, the fall of global commodity prices and a weakening of foreign investment led to a slowdown in economic growth after 2010, and in 2014 Brazil witnessed a sharp decline in the gross domestic product (GDP), entering in a period of deep depression. Despite the government has implemented a set of economic stimulus measures, such as price controls, tax breaks, reduced interest rates, and subsidized public funds loans, these measures have done little to improve the economy and the recession increased unemployment. Only in 2015, 1.6 million formal jobs were lost, inflation rose and investments declined. In the wake of the economic crisis, in 2013 a political instability emerged, and citizen protests against corruption and demands for better public services spread all over the country. After a series of corruption scandals, the progressist President Dilma Rousseff was impeached in 2016 based on a controversial accusation of financial irregularity. A new center-

right government was installed, and in 2016 the Congress enacted a Constitutional Amendment limiting federal primary health spending over the next 20 years, limiting spending in 2017 to 15% of current net revenue and, thereafter, to 2017 spending levels adjusted for inflation, with a projected drop in the health budget of R$ 415 billion by 2036.

From 2000 to 2014, the total expenditure in health rose from 7.0% to 8.3% of GDP, and per-capita health expenditure increased from US$263 in 2000 to US$947 in 2014. The total health expenditure in Brazil is comparable to other Latin American countries, although public expenditure is low for a universal healthcare system, overburdening individuals with large out-of-pocket costs. Brazil has one of the lowest proportions of public spending on health (46.0%) when compared with upper-middle-income countries (55.2%). Between 2003 and 2014, the total municipal health expenditure per capita (including own resources and revenues from federal and state sources) grew 226%, from R$315.7 to R$716.5 (after inflation). However, from 2015 to 2016 per-capita expenditure decreased 6.3% to R$617.1. Also, between 2003 and 2016, the federal government's share of health financing fell from 50.0% to 40.8% of total public health expenditure (Massuda A 2018).

Figure 2 Infant mortality rate (IMR) and under-five-years mortality rate (U5MR) in Brazil , 2007-2016 (SIM-TABNET/DATASUS/Health Ministry: http://tabnet.datasus.gov.br/cgi/tabcgi.exe?sim/cnv/evita10uf.def)



After this period of economic and political turmoil, under-one-year infant mortality (IMR) and under-five-year infant mortality rates (U5MR), that raised from 12.43 deaths to 12.72 deaths per thousand live births and from 14.28 deaths to 14.89 deaths per thousand live births, respectively (Figure 2) (Observatório de Saúde da RMSP 2018; Abrasco 2018). These facts call attention to the

possible impact of Social Determinants of Health (SDH) on infant mortality rates in Brazil after the implementation of these health and social policies.

This anomaly in the trend of child mortality, particularly when combined with regional disparities and a slow decrease in the decline in infant mortality rates is of great concern and raise questions about what is the extent of these health and social policies on the country's ability to maintain a longer-term decline in the infant mortality rate, capable of placing this rate at the level of developed countries and what are the determinants of infant mortality in Brazil after the implementation of these public policies?

The problem can be approached from different analytical perspectives. Some theoretical frameworks like that proposed by Mosley & Chen (Mosley and Chen 2003) allow us to analyze the mechanisms by which the SDH operate at the intermediate or proximal levels of causes that directly affect the health of individuals. Mosley & Chen postulates that studies on the SDH treat the mechanisms that act directly on the health of the individual as black boxes, without explaining why a given factor is associated with child mortality. Since the publication of the model proposed by Mosley & Chen, many studies in developing countries have used this theoretical framework (De Souza et al. 2001; Fikru, Getnet, and Shaweno 2019; Lansky et al. 2014; Barbosa 2014) by adapting the categorization of health determinants initially proposed at distal, intermediate and proximal levels, which allows the analysis of the roles and the relationships between these categories to a given health outcome.

However, methodologies have evolved considerably in recent years and new social and health issues have emerged in the last decades. Social inequalities, health inequalities and inequalities in the access to public services have been included in the public health agenda (WHO 2010), which have allowed the emergence of new models such as the determinants of health model proposed by the WHO's Commission on Social Determinants of Health (Solar 2010).

In front of this new context, we decided to conduct our research according to an economic perspective. As other studies on child mortality (Shandra, Shandra, and London 2011; Boehmer and Williamson 1996), we opted for a Macro/Social/Economic approach. This approach grounded in economics allow us to take a macro perspective focused on the trends in health indicators related to the role of the macro social environment and public policies as relevant in determining health outcomes. Such perspective based on upstream factors may keep public policies away from explaining the mechanisms by which the black box of SDH act on proximal causes of infant

mortality, having in mind that policymakers should make decisions based on the best available knowledge, derived from diverse sources and methods (Braveman et al. 2011).

The objectives of this thesis

The general objective of this dissertation was to identify the determinants of infant mortality in Brazil after the implementation of FHS and BFP to raise plausible hypotheses for the slowdown, the regional disparities and the anomaly in the trend of declines in the infant mortality rate in Brazil. To respond to this general objective, we seek to achieve three objectives:

1: Identifying and summarizing the determinants of infant mortality in Brazil based on a scoping review, with a view to raising hypotheses for the recent changes in the infant mortality rates in Brazil and identifying gaps in terms of research concerning the determinants that may impact infant mortality in Brazil based on the Conceptual Model of Health Capability (CMHC);

2. To conduct a descriptive and retrospective analysis of the determinants of infant mortality in Brazil between 2004 and 2015, based on the model of World Health Organization's Commission on Social Determinants of Health (CSDH) framework aiming at analyzing the evolution of these determinants to understand the behavior and disparities of infant mortality rates observed in recent years in the country.

3.To perform a panel data analysis as a methodological proposal in order to identifying the factors impacting mortality in Brazil according to the CMHC, aiming at raising plausible hypothesis to explain the behavior and the disparities of infant mortality observed in recent years in Brazil, after the implementation of Family Health Strategy and *Bolsa Família* programs.

Presentation of the three articles of the thesis.

Three articles form the basis of this thesis and aim at identifying the determinants of infant mortality in Brazil after the implementation of the FHS and PBF programs, and at understanding the recent changes in the country's infant mortality indicators. The first article performed a scoping review on the determinants of infant mortality in Brazil. The search included articles published in indexed scientific journals in the last ten years. The review selected studies conducted after 2004, when FHS and BFP were already implemented. In the second article, we conducted a descriptive retrospective analysis according to the perspective of Public Health by adopting the analytical framework proposed by the WHO's CSDH. The study was building on data from under-one-year-

old infant mortality in Brazil and its determinants, according to the findings of our scoping review (article 1). This article aimed at assessing a possible correlation between infant mortality and the independent variables and analyzing their evolution between 2004 and 2015. The third and last article proposed a methodology to overcome the challenges of developing a panel data model using aggregated data from the 26 Brazilian states and macro-regions, according to the theoretical framework of the CMHC, with a view to inferring possible associations between our independent variables and infant mortality rates in Brazil, to allow us to raise hypothesis about the recent changes in the country's infant mortality indicators.

In the following subitems we provide further information about these three articles.

1.1.1 Article 1: *"The Determinants of Infant Mortality in Brazil 2010-2020: a scoping review"*

This article identified that despite the increase in supply and demand for health services provided by the combination of the FHS and BFP programs, socioeconomic inequalities may lead to inequalities in access to quality and comprehensive services, which generates health inequalities. This suggests that in the presence of these inequalities, these policies are limited in providing a long-term response to a sustainable reduction in infant mortality rates in Brazil. Factors such as income and life conditions, such as housing, access to employment, and education, were also identified as important determinants of child mortality in the last decade in Brazil. The review also suggests that the anomaly of the declining trend in IMR and U5MR would have been caused by a decrease in income and employment that had an impact on living conditions and access to health services. The literature review identified a lack of studies on the possible effects of employment, regardless of income, on infant mortality in the country. Findings shed light on the limited capacity of social and health policies in promoting sustainable reductions in infant mortality in Brazil, mainly in the presence of socioeconomic inequalities. This paper also identified a gap in terms of studies on a possible direct relation between employment and infant mortality.

1.1.2 Article 2: "*The Determinants of Infant Mortality and Public Policies in Brazil 2004-2015: a descriptive analysis*"

In the second study, we conducted a descriptive retrospective analysis of the evolution of the determinants of infant mortality in Brazil. The analysis was supported by the framework of the WHO's CSDH, which breaks down the determinants of health into two groups: structural

determinants, which in turn is subdivided into two subsets: socioeconomic and political context, and socioeconomic position; and intermediary determinants, which in turn is also subdivided into material circumstances, behavior, biological and psychosocial factors influencing the effectiveness of the health system. We identified a clear declining trend of IMR in all regions of the country, although inequalities in infant mortality were observed in the North and Northeastern states, related to inequalities in socioeconomic and health-related factors. Findings point out that inequalities in infant mortality are related to disparities in the distribution of social determinants of health such as income, BFP coverage, education attainment, employment, fertility rate and of health-related determinants such as quality of and accessibility to healthcare and water supply, as well as sewage services. The results also suggest that these disparities limit further reductions in infant mortality, which would probably explain both the slowdown in the reduction and the tendency of the infant mortality rate to remain at relatively high levels.

1.1.3 Article 3: "*Health Capabilities and the Determinants of Infant Mortality in Brazil 2004-2015: an innovative methodological framework"*

In the third study, we performed a panel data model using aggregated data from the 26 Brazilian states and different subregions according to the CMHC, with a view of inferring possible associations between our independent variables and infant mortality rates in Brazil, aiming at raising hypotheses about the recent changes in the country's infant mortality indicators. This study showed that it is possible to operationalize estimations through a model of multilevel panel data with fixed effects nested in clusters based on the CMHC. The estimations were able to isolate the effects of the variables under study from factors not observed, which are subject to estimation errors due to different degrees of error homogeneity within and between clusters. Our models allowed us to infer more about specific factors related to infant mortality rates such as the relation between the employment rate and infant mortality and between the BFP and neonatal mortality, or the threshold of household income that acts as a protective factor for infant mortality. Furthermore, the use of this methodology is a low cost-benefit solution, considering that it relies on a low volume of data when compared to conventional panel data studies.

The relevance of this thesis

This study contributes to the current state of knowledge of the determinants of infant mortality in Brazil, which has mainly been focused on social and health interventions and characterized by the

use of social factors as control variables. This dissertation offers an innovative analytical and methodological approach, contributing to filling existing gaps in regard to the social determinants of health in Brazil.

Organization of this thesis

This introductory chapter included, this thesis consists of 6 chapters. Chapter 2 presents a literature review aiming to update evidence on the factors influencing infant mortality in Brazil, after the implementation of the FHS and BFP programs. At the end of this chapter, the first article: *The determinants of infant mortality in Brazil 2010-2020: a scoping review* was included, followed by a subsection with the synthesis of the state of knowledge on the determinants of infant mortality in Brazil and by a subsection introducing the two conceptual frameworks used in this dissertation. Chapter 3 presents the methodology applied in articles 2 and 3. In Chapter 4 we present articles 1 and 2 and their results. In Chapter 5 we present a discussion by returning to the main results of the three articles, with a view to providing plausible explanations for the behavior and the recent changes in infant mortality rates in Brazil in regard to the capabilities approach, aiming to suggest policies and actions, and as well to propose new research studies on infant mortality. This chapter also presents the limitations of the thesis and proposes possible avenues to be taken in terms of research on the social determinants of infant mortality in Brazil and other health-related subjects as well. The conclusions in chapter 6 address the research objectives proposed in the present thesis.

Chapter 2 Literature review

This chapter presents a literature review based on a scoping review of quantitative studies previously published on the determinants of infant mortality in Brazil. This chapter consists of three subsections. Subsection 1 presents article 1 with the scoping review. In subsection 2 we present a synthesis of the main characteristics of current studies on the determinants of infant mortality in Brazil aiming at identifying limitations and research gaps. Subsection 3 introduces the two conceptual frameworks adopted in the current dissertation: the WHO's CSDH conceptual framework and the CMHC.

Article 1. The determinants of infant mortality in Brazil 2010-2020: a scoping review

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ABSTRACT

No study sought to review evidence on the determinants of the different infant mortality indicators in Brazil at a national level. We aimed to fill this research gap by conducting a scoping review based on the CMHC, in order to identify the quantitative studies that have addressed this subject in the last decade, with a view to identifying and analyzing these determinants after the implementation of the FHS and the BFP. Our results suggest that despite innovative policies that emerged with the implementation of the SUS, inequalities in the access to comprehensive and quality healthcare seem to have important implications in reducing infant mortality rates. Socioeconomic conditions and health-related factors interacting in the four dimensions of the CMHC such as income, educational attainment, fertility rate, housing access to healthcare and BFP coverage rate were pointed out as the main determinants of infant mortality. Recent changes in infant mortality in Brazil are likely related to changes in those factors. This study also shed light on the limited capacity of social and health policies in promoting sustainable reductions in infant

mortality in Brazil, mainly in the presence of socioeconomic inequalities. We also identified a gap in terms of studies on a possible direct relationship between employment and infant mortality.
Keywords: Infant mortality, health capabilities, public policies, social determinants of health, conditional cash transfer program

The determinants of infant mortality in Brazil 2010-2020: a scoping review

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Background

Despite the implementation of social and health policies that positively affected the health of the populations in Brazil in recent decades, since 2009 the country has experienced a slower decline of infant mortality. After an economic crisis that evolved into a troubled period of political crisis, in 2016 the country witnessed increases in infant mortality rates that raised questions about the determinants of infant mortality in Brazil after the implementation of such policies.

Methods

We conducted a scoping review to identify and summarize the determinants of infant mortality in Brazil under the influence of the Family Health Strategy (FHS) and *Bolsa Família* Program (BFP), with a view to raising hypotheses for the recent changes in the infant mortality rates and identifying gaps in terms of research concerning the determinants that may impact infant mortality in Brazil, with searches in three databases: LILACS, MEDLINE, and SCIELO. We included quantitative studies on infant mortality in Brazil by all causes subjected to healthcare promotion and/or prevention, published between 2010 and 2020. The search was restricted to studies that ended after 2004 when the current policies were already in place. We analyzed the results based on the Conceptual Model of Health Capability (CMHC).

Results

We selected 23 papers of which 82.6% associated infant mortality with public policies; 78.3% related infant mortality with the use of the health system and socioeconomic conditions; and 26% related individual characteristics to infant mortality.

Conclusion

The objective of this scoping review was to identify the determinants of infant mortality in Brazil under the influence of social and health policies, with a view to raising hypotheses for the recent changes in the infant mortality rate and identifying gaps in research concerning such determinants. Despite the innovative policies that emerged with the implementation of the Brazilian Unified Health System (SUS - *Sistema Único de Saúde*) , inequalities in the access to comprehensive and quality healthcare seem to have important implications in reducing infant mortality rates. Our findings suggest that although the FHS and PBF programs have increased the availability and boosted the demand for healthcare, the access to maternal and childcare still remain as a critical factor influencing infant mortality that also depends on private healthcare. Socioeconomic conditions and health-related factors interacting in the four dimensions of the CMHC such as income, educational attainment, fertility rate, housing, access to healthcare and the BFP coverage rate were pointed out as the main determinants of infant mortality. Likewise, recent changes in infant mortality in Brazil are likely related to changes in those factors. This study also shed light on the limited capacity of social and health policies in promoting sustainable reductions in infant mortality in Brazil, mainly in the presence of socioeconomic inequalities. Likewise, recent changes in infant mortality in Brazil are likely related to changes in those factors. We also identified a gap in terms of studies on a possible direct association between employment and infant mortality. More quantitative studies are needed to assess the impact of those determinants on infant deaths.

Keywords: Infant mortality, health capabilities, public policies, social determinants of health, conditional cash transfer program

2.1.1 Background

The infant mortality rate is a reliable indicator of population health and effectiveness of health systems that is also capable of estimating the extent of social and health inequalities between different populations [1-3]. Over the past 25 years, although many Latin American countries achieved a decrease in infant mortality rates, this trend has slowed down in comparison with other regions [4]. Similarly, and despite the implementation of a set of social and health policies that positively affected the health of populations in Brazil [5], since 2009 Brazil has been experiencing a slower decline in infant mortality [6] that has remained at high levels and presents significant regional disparities. In 2016, the country even recorded an increase in the mortality of children under-one and under-five years old, which represents an anomaly of that downward trend [6, 7].

A new Constitution enacted in 1988 has established the right to health as a universal human right and an obligation of the State. The Constitution laid the grounds for the implementation of the Unified Health System (SUS – *Sistema Único de Saúde*). The main objectives of the SUS were: universality, equity, integrality, decentralization, hierarchization and community participation.

In 1994, the Brazilian Ministry of Health created the Family Health Program (now operating under the name of Family Health Strategy (FHS)). The FHS was a decentralized program based on community healthcare that sent healthcare professionals into communities to deliver primary healthcare. Before the implementation of the FHS, public healthcare was based on a hospital-centered model and the assistance provided to the population focused on medium-high complexity sectors, causing a greater demand for resources and low resolution [5].

Created in 2003, the *Bolsa Família* Program (BFP) provides monthly cash transfers to poor families on the condition that they meet the program's health and educational conditionalities. Cash transfers were made preferentially to women through credits to beneficiaries' electronic cards. The health conditionalities of the program established that parents were required to ensure that children younger than seven years of age had to comply with a routine of check-ups and growth monitoring and a childhood vaccination program. Pregnant women and nursing mothers were expected to be engaged in care and nutritional education programs in their local healthcare provider. The educational conditionalities stipulated that children aged 6–17 years had to be enrolled in school and keep a minimum attendance rate according to their age bracket [8].

Since the implementation of the SUS and the creation of both programs, health indicators have improved, and progress has been made in reducing inequalities across the country. Over the last 30 years, increased life expectancy, declines in maternal and infant mortality and a sharp decline in mortality due to transmissible diseases, among other improvements were observed [9].

After an economic crisis that evolved into a troubled period of political crisis, in 2016 many regions reported an increase in the infant mortality rate [6, 10, 11]. This anomaly in the in the trend of declines in infant mortality when combined with regional disparities and the stabilization trend of infant mortality at high levels are of great concern.

According to the World Health Organization (WHO), maternal and child health are closely related to social determinants of health that go beyond the impacts of adequate health. Thus, infant health is also influenced by non-healthcare policies targeting socioeconomic and living conditions, which are as important as health policies for infant survival.

Thus, these changes in infant mortality rates raise questions about what the determinants of infant mortality in Brazil under the influence of such social and health policies are. In order to answer this question, we conducted a scoping review to identify and summarize the determinants of infant mortality in Brazil under the influence of the FHS and BFP, with a view to raising hypotheses for the recent changes in the infant mortality rates and identifying gaps in terms of research concerning the determinants that may impact infant mortality in Brazil.

2.1.2 Methods

Scoping review framework

The methodological approach employed was the framework proposed by Arksey & O'Malley [12] which breaks down the scoping review into 5 steps: Stage 1. Identifying the research purpose; Stage 2. Identifying relevant studies; Stage 3. Study selection; Stage 4. Charting the data, and Stage 5. Collating, summarizing and reporting the results. In line with this approach, the steps above allow for reviewing the existing literature and examining the extent, scope and nature of research activities on a given subject, in addition to identifying gaps, summarizing and disseminating research results.

Identifying the research question

As stated above, this review aimed to answer the following question: what are the determinants of infant mortality in Brazil under the influence of such social and health policies? We had two objectives:

1. Raising hypotheses for the recent changes in the infant mortality rates in Brazil.
2. Identifying gaps in terms of research concerning the determinants that may impact infant mortality in Brazil.

Identifying the relevant studies

Inclusion and exclusion criteria

We included indexed quantitative studies on infant mortality by preventable causes according to the Brazilian List of Causes of Avoidable Deaths by Interventions of the SUS, as follows: a) avoidable by immunoprevention actions; b) avoidable by providing adequate care to women during pregnancy and childbirth and to the fetus and newborn; c) avoidable by appropriate diagnostic and treatment actions and d) avoidable by appropriate healthcare promotion actions linked to appropriate healthcare actions [13, 14].

Regarding the concept of infant mortality, we sought studies on the determinants of the following indicators: neonatal mortality rate (NMR; between 0 and 27 days of life), early neonatal mortality rate (ENMR; between 0 and 6 days of life), late neonatal mortality rate (LNMR; between 7 and 27 days of life), under-1 infant mortality rate (IMR; between 0 and 1 year of age) and under-5 child mortality rate (U5MR; between 0 and 5 years of age). We have included perinatal mortality (PMR) in our search, which occurs between the twentieth week of pregnancy (approximately 122 days) and the seventh day of life. Our objective in doing so was to identify studies concerning early neonatal death, which considers the deaths from delivery to the seventh day of life. In this study, when referring to infant mortality without mentioning a specific interval, we mean the overall infant mortality.

The research interval included studies published between 2010 and 2020, with observation intervals that ended after 2004, when the current social and health policies were already in place. The searches were conducted from January 4th to February 5th, 2020 and the selection was restricted to studies written in French, English, Portuguese, and Spanish. Brazil has 5570 municipalities and a population of approximately 210 million, distributed into five macro-regions with very different socioeconomic characteristics. Studies carried out in very specific regions and institutions had little or no relevance for this review. We established the country, the federal states, the five macro-regions and the municipalities in their entirety or a representative proportion of the national territory and/or population as study units. Although it is unusual to have regional and methodological restrictions as exclusion criteria in scoping reviews, Armstrong et al. [15] suggest that regional and population limitations are valid tools to avoid selecting studies of low relevance. We also excluded the gray literature and texts with abstract only, editorial articles, letters from editors, correction letters, articles without a clear methodological approach, methodological analysis, opinion articles, quality assessment articles, data accuracy articles and information systems analysis.

Search criteria

We searched for articles published in scientific reviews indexed in three databases: MEDLINE (US National Library of Medicine), LILACS (Latin American and Caribbean Literature in Health Sciences) and SciELO (Scientific Electronic Library Online). Table 1 presents descriptors and keywords used in the research according to each database. The research equations were analyzed and reviewed by an expert library scientist.

Table 1 Descriptors and keywords used according to database*

MEDLINE	**MeSh** descriptors:** ((mortali* or death* or fatali*) adj3 (neonatal* or neo natal* or new born* or newborn* or infant* or child* or baby* or babies* or kid* or kids* or paediatric* or pediatric*)).ab,kf,kw,ti. **Keywords:** "death" "fatality", "neonatal", "neo natal", "newborn", "new born", "child", "baby", "babies", "kid", "kids", "paediatric" and "pediatric"
LILACS	**Descriptors:** Concept 1: mh:(mh:(((((mortality OR death OR "cause of death") AND (child OR infant OR "infant, newborn")) OR ("child mortality" OR "infant mortality" OR "perinatal mortality")) AND (brazil))) AND (db:("LILACS")) AND (year_cluster:[2010 TO 2020]))" **Keywords:** w:((mortali* OR death* OR fatali*) AND (neonat* OR "neonat*" OR newborn* OR "new born*" OR "recém nascido*" OR infant* OR child* OR crianca AND (brasil* OR brazil*)) AND (db:("LILACS")) AND (year_cluster:[2010 TO 2020]) AND (db:("LILACS"))
SciELO	**Keywords:** (mortali* OR death* OR fatalit*) AND (neonatal* OR "neonatal*" OR "new born*" OR newborn* OR infant* OR child* OR crianca OR "recém nascido") AND (brasil* OR brazil*) AND year_cluster:("2013" OR "2014" OR "2019" OR "2017" OR "2011" OR "2018" OR "2010" OR "2016" OR "2012" OR "2015")
* Database descriptors, keywords and search equations are fully described in Appendix. 1 ** MeSH refers to Medical Subject Headings database descriptors	

Study selection

In the first stage, after eliminating duplicates, based on title and abstracts we excluded non-relevant articles. In the second stage, we read all articles and then excluded those with no relevance to our research purposes according to the exclusion criteria.

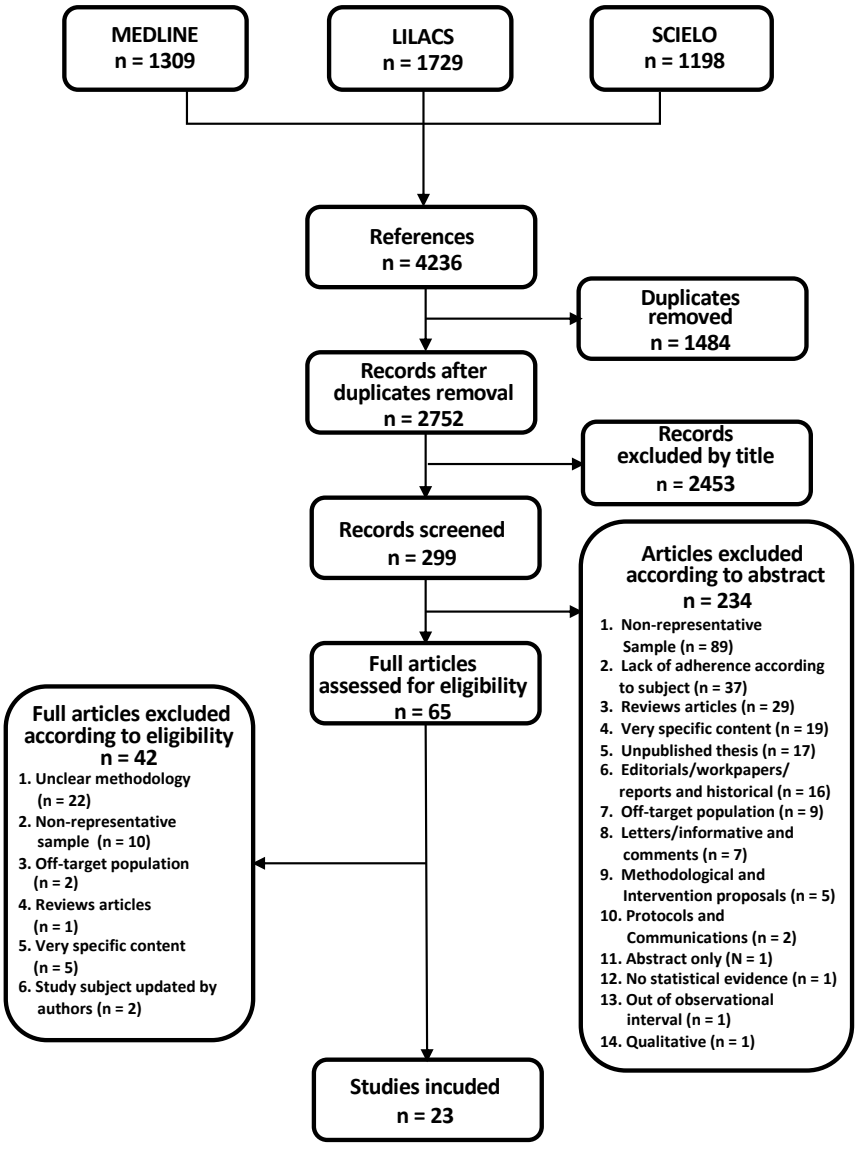
In the third stage, a critical reading of the eligible articles was carried out, respecting the following inclusion criteria: study unit, population, relevance of the study to our research purposes, and methodology. We used the Mixed Methods Appraisal Tool (MMAT) grid to evaluate the quality of the selected studies (Appendix 2). The MMAT was designed as a critical checklist to provide a quality appraisal tool for quantitative, qualitative, and mixed methods studies. This grid is quite complete and at the same time easily adaptable for the inclusion of new fields and information such as indicators of child mortality. The use of this tool is suitable for many types of quantitative studies in health, as it is not only focused on randomized or case-control studies but allows the use in quantitative research also based on literature reviews and surveys (Hong 2018a; Hong 2018b). The use of the MMAT allowed us to assess eligible articles in order to identify and select those capable to provide evidence to answer our research questions. We established a minimum score of

80% in terms of methodological quality for an article to be included in this scoping review. The reading grid assessed studies characteristics regarding if there is an explicit methodological approach, clear objectives, and research purposes, if there is a clear explanation of variables, if data is likely to answer the research questions, and if they are complete.

Selected studies

As seen in Figure 1, a total of 4236 titles were identified in the three databases. 1484 duplicates were eliminated, and 2453 publications were excluded because of lack of relevance by title. 299 articles were retained and 234 were eliminated because of lack of relevance by the abstract. Finally, after reading 65 eligible papers, 23 studies fully met the selection criteria.

Figure 1 Study selection flow chart

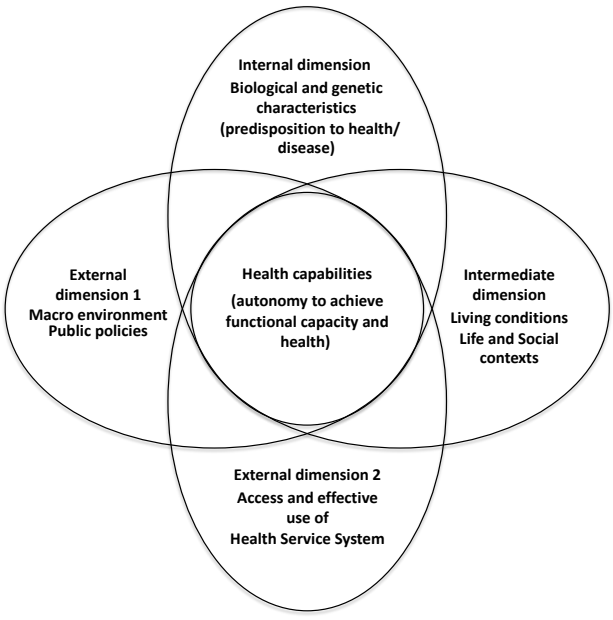


Charting the data, summarizing and reporting the findings

To extract data from articles, to organize and to provide logical sense to our findings in respect to the Brazilian context, we used the Conceptual Model of Health Capability (CMHC) developed by Ruger [18] (Figure 2).

Under the perspective of the capabilities approach, rights are understood in a positive way for which they require affirmative government support for their creation and preservation [19]. After enacting the 1988 Constitution, Brazil has established health as a basic human right and an obligation of the State. In this sense, conditional cash transfer programs such as BFP are designed to motivate people to seek health and educational services through monetary incentives in exchange for families observing the program's conditionalities [8]. In this same line, the central idea of the CMHC is that individuals seek both health and the ability to seek health. Based on the concept of capabilities of the Nobel Prize in Economics Amartya Sen [20, 21], this conceptual framework considers the individual's sense of health and functional capacity to attain health capability as the result of the interaction of four dimensions. The CMHC hypothesis is that an individual's health is the result of the interaction of an external dimension which refers to the macro, social, political and economic environment, a second external dimension related to the effective use of the health services system, an intermediate dimension referring to the social and life contexts, and an internal dimension corresponding to the individual's biologic and genetic predisposition to health/disease.

Figure 2 Adapted from the Conceptual Model of Health Capability [18]



In this framework, there is a fine line between State paternalism and self-agency as drivers to an individual, or a population, for pursuing and maintaining health as social and economic values.

The concept of health capabilities has become increasingly important as an approach for assessing health. Further, infant mortality is considered as an appropriate indicator of population health attainment (health functioning), while the social determinants of health, such as education, housing, employment and economic inequalities are social and environmental conversion factors (capabilities) [22].

As a useful resource applied to other studies of the determinants of health that used an adapted framework on the determinants of health [23] and considering the specificities of social and health policies implemented in Brazil, we introduced some changes in the original CMHC framework, in order to identify the factors that are likely to effect on infant mortality in Brazil.

Regarding external dimension 1, we considered the results of social and health policies and actions into the macro-environment, such as decentralization of resources and services, increased coverage of healthcare, and results of non-directly health-related policies such as income, employment and other socioeconomic factors.

Internal dimension 2 encompasses both access to and effective use of the health system. A clarification is needed in this respect. In Brazil, the health services system consists of two healthcare subsystems: a public health system, which comprises the SUS and its private partners and non-profit organizations, and a private healthcare sector that provides supplementary health through direct payments (out-of-pockets) and/or through contracts of supplementary health insurance. Thus, in this study, when we refer to the health services system, we mean the services provided by both the public (SUS) and the private sector.

In relation to the intermediate dimension, we used the concept of living conditions in a broader sense. It means that, in addition to housing, sanitation, safe water supply and income, we also consider poverty, income, social and health inequalities, nutrition status, teenage pregnancy, late pregnancy, unemployment, fertility, culture, educational and religious attainment as life and social contexts in the intermediate dimension.

In the internal dimension, we maintained the individual's genetic and biological characteristics, as determinants of predisposition to health/disease.

Although the CMHC was conceived aiming at the conceptualization and operationalization of health interventions at the individual level, the proposed version aims at identifying the

determinants of infant mortality after the implementation of the FHS and BFP programs at the population level.

2.1.3 Results

Determinants of infant mortality in Brazil

We begin our analysis by presenting the studies included in our review (Table 2) and by summarizing the findings according to the CMHC dimensions (Table 3), and finally by reporting the results.

Table 2 Studies included

Main author	Period	Sample/study unit	Indicator	Methods	Objective
ALMEIDA, W. /2012[24]	2005-2007	Newborns and deceased infants in the 5,564 municipalities	IMR	Ecological study with geospatial analysis	To analyze geographic access to childbirth in hospital in Brazil municipalities and IMR
ARAÚJO, C. /2017[25]	2010	Deceased children of mothers living in 5,526 municipalities	IMR	Retrospective descriptive analysis	To evaluate the effect of municipal per capita spending on health on IMR
BOSCHI-PINTO, C. /2017[26]	1990-2015	Populations and regions of 75 low and middle-income countries with high burden of diarrhea and pneumonia, including Brazil	U5MR	Ecological study	To explore whether the adoption of national policies for the management of pneumonia and diarrhea is associated with the decline of U5MR
BÜHLER, H. /2014 [27]	2010	Deceased children under-one year from mothers who lived in the 558 health micro-regions	IMR	Ecological study with geospatial analysis	To study environmental indicators for diarrhea in children under one year of age in Brazil and IMR
FRANÇA, E. /2017[28]	1990-2015	Deceased children under-five and general population	U5MR	Ecological study and statistical analysis	To analyze the leading causes of U5MR, using estimates from the Global Burden of Disease Study (GBD) 2015
GARCIA, L. /2011[29]	1993-2008	Macro-regions, units of the Federation and nine metropolitan regions	IMR /U5MR	Cross-sectional study	To study the temporal evolution and the extent of inequalities in infant and child mortality
GOMES,T. /2016[5]	2000-2011	Under-five deceased children in Brazil and macro-regions	U5MR _	Ecological study with time series	To analyze the trends in childhood mortality in Brazil and regions study the correlation between acute diarrheal disease and acute respiratory infection and U5MR
GUANAIS, F. /2013[30]	1998-2010	Deceased children of families benefiting from the BFP and FHS living in 4,853 municipalities	NMR /PNMR	Panel data	To examine the combined effects of (FHS) and BFP on NMR and PNMR
MALTA, D. /2019[14]	2000-2013	All under-five children deceased in Brazil and macro-regions	U5MR	Ecological study with time series	To analyze the trend in U5MR according to the list of preventable causes of death
MARTINS, P. /2018[31]	2000-2010	Children under-one deceased from mothers living in the states and macro-regions	IMR	Ecological study	To analyze the convergence between the decrease in IMR

					and the Municipal Human Development Index
MENDES, P. /2013[32]	2000-2010	Under-one and under-five deceased children in the 5 macro-regions	IIMR /U5MR	Ecological study with time series	To analyze the temporal trends of indicators of IMR and U5MR related to hospital morbidity due to diarrheal diseases
OLIVEIRA,G. /2013[33]	2006-2010	Newborns deceased in the 26 states and the Federal District, Brasília	NMR	Ecological study with geospatial analysis	To analyze the spatial distribution of neonatal mortality and its correlation with biological, socioeconomic, maternal and child factors
RAMALHO,W. /2013[34]	2006-2008	Children deceased between 27th and the 364th day of life in the 5,227	NMR, /ENMR /LNMR /PNMR	Ecological study	To describe the inequalities in infant mortality according to socio-economic indicators between geographic areas and municipalities in Brazil
RASELLA, D. /2010[35]	2000-2005	Children under-five who died in Brazilian municipalities	NMR /IMR /PNMR /U5MR	Panel data	To assess the effects of the FHS on the U5MR due to diarrhea diarrheal diseases and lower respiratory tract infections
RASELLA, D. /2013 [36]	2004-2009	Children under-five who died in 2853 municipalities.	U5MR	Panel data	To assess the effect of BFP on deaths of children under-five, associated with poverty, diarrhea, lower respiratory tract infections and malnutrition
RODRIGUES,N. /2016[37]	1997-2000 2001-2004 2005-2008 and 2009-2012	Deceased children from mothers living in the 5 macro-regions	ENMR /LNMR	Ecological study with geospatial analysis	To assess the spatial and temporal trends of maternal and neonatal mortality.
RUSSO, L. /2019[38]	2005-2012	Deceased children under-one year in 5,563 municipalities	IMR	Panel data	To study the effect of primary care physicians on IMR
SCHUCK-PAIM, /2019[39]	1980-2010	Children under-five who died from pneumonia from mothers living in the 5,570 municipalities	U5MR	Retrospective descriptive analysis	To assess the effect of ten-valent pneumococcal conjugate vaccine (PCV10) on under-five mortality from pneumonia
SHEI, A. /2013[8]	1998-2008	Infant deaths in all municipalities in the country.	NMR, /PNMR /IMR	Times series study	To examine whether the implementation and expansion of the BFP Program, was associated with infant mortality
SILVA, A.A. /2010[40]	1995-2007	Deceased children in the five Macro-regions and the 26 states and the Federal District, Brasília	IMR	Correlational descriptive study	To examine whether the low birth weight (LBW) paradox exists in Brazil
SILVA, A.L.D. /2016[41]	1999-2013	The country's population (women of childbearing age, children born alive and deceased in the national territory	NMR /IMR	Ecological time series	To analyze childbirth assistance according to birth profile, characteristics of live births and preventable infant deaths

VERONA, A. /2010[42]	1996-2006	Under-one children deceased from mothers aged 15 to 49 who had at least one child in the five years preceding the survey	IMR	Correlational analysis	To examine the relation between IMR and religious involvement of mothers
VIEIRA-MEYER, A. /2019[43]	2012	Under-one deceased children from mothers living in 3441 municipalities	IMR	Ecological study	To access how the coverage and quality of FHS and BFP are associated with IMR

Table 3 The determinants of infant mortality according to the four CMHC dimensions

Main author/year	External Dimension 1*	External Dimension 2*	Intermediate Dimension*	Internal Dimension*
ALMEIDA,W. /2012[24]	Socioeconomic conditions	Unequal access and quality of healthcare /Organization of healthcare at region level	Distance to the place of delivery, socioeconomic and cultural factors	–
ARAÚJO,C. /2017[25]	Per capita spending of municipality's own resources on healthcare	Unequal access to healthcare	Living conditions	–
BOSCHI-PINTO,C. /2017[26]	National policy of management for treating pneumonia and diarrhea/ The Millennium Development Goal SDG-4	–	–	–
BÜHLER, H. /2014 [27]	Socio-environmental policies	–	Percentage of residents without garbage collection service and dependency ratio	–
FRANÇA, E. /2017[28]	BFP/ National Immunization Program/FHS/	Primary healthcare /reorganization of prenatal and neonatal care	Improvements in / nutrition	Prematurity/congenital anomalies
GARCIA, L. /2011[29]	Regional socioeconomic inequalities/ household per capita income	–	Maternal schooling and living conditions	–
GOMES, T. /2016[5]	Expanding coverage of FHS/ improvements in socioeconomic conditions	Increase in the population covered by primary care	–	–
GUANAIS, F. /2013[30]	The expansion and interaction o FHS and BFP programs	Quality of hospital birth care	Improvements in daily living conditions	–
MALTA, D. /2019[14]	SUS/ Healthcare promotion actions linked to healthcare actions	Adequate neonatal care/diagnostic/ therapeutic actions and care during childbirth	–	Short-term pregnancy and low birth weight (LBW)
MARTINS, P. /2018[31]	Regional socioeconomic disparities	–	Living conditions expressed by Municipal Human Development Index (MHDI)	–

MENDES, P. /2013[32]	Healthcare policies and socioeconomic inequalities	Limited access to healthcare	Socioeconomic and cultural disparities	–
OLIVEIRA, G.S. /2013[33]	Macroeconomic policies/BFP/ socioeconomic and regional inequalities	Inequalities in accessing maternal/ prenatal/ birth care and cesarean sections	Living conditions/ maternal education/ Low Birth Weight Paradox (LBWP)/	Maternal age/ teenage pregnancy/ LBW
RAMALHO,W. /2013[34]	Socioeconomic conditions measured by Family Development Index (FDI)	Coverage of Healthcare/ healthcare Information System	(FDI)/ family vulnerability/social mobilization	Congenital malformation
RASELLA,D. /2010[35]	FHS coverage	Reorganization of Primary healthcare/ early case diagnosis/ antibiotic prescription	socioeconomic conditions	–
RASELLA, D./ 2013 [36]	BFP/ FHS coverage	Increased primary care through BFP	Extreme poverty/ undernutrition	–
RODRIGUES,N. /2016[37]	–	Unequal distribution of healthcare among the macro-regions	–	–
RUSSO, L. /2019[38]	Gross Domestic Product per capita/ FHS	Availability of primary care physician/ private health insurance coverage	Gross Domestic Product per capita/piped water/electricity/garbage collection	–
SCHUCK-PAIM, C. /2018[39]	National Immunization Program	Vaccination/improved education and healthcare	Improved nutrition and hygiene	–
SHEI, A. /2013[8]	Expanding coverage of the PBF	Improved access to healthcare	Reduction of health inequalities:	–
SILVA, A.A. /2010[40]	–	Healthcare during pregnancy/early medical interventions	Socioeconomic conditions/maternal education	LBWP
SILVA, A.L. /2016[41]	–	Hospital quality/ increased use of health private sector	–	LBW
VERONA,A. /2010[42]	–	–	Maternal religious involvement, parity and region	–
VIEIRA-MEYER,A. /2019[43]	FHS and PBF coverages	Quality and effectiveness of FHS	Socioeconomic conditions/Human Development Index (Wang et al.)/family attitude towards health	–

(*) As indicated in the CMHC, Internal dimension 1 refers to the outcome of the macro-environment; external dimension 2 is related to the access and effective use of health system; the intermediate dimension is linked to social and life context, while the internal dimension refers to biological and genetic individual characteristics

The four dimensions of CMHC

In this section we reported the findings according to the dimensions of the CMHC, by summarizing the main results at the end of external dimension 2 (summary of findings related to dimensions 1 and 2), intermediate and internal dimensions, respectively.

External dimension 1 – Macro-environment/outcome of public policies

A majority of papers associated infant mortality with the macro-environment and the outcome of public policies [5, 8, 14, 24-36, 38, 39, 43] (n=19; 82.6%). Healthcare policies accounted for 56.5% (n=13) of the of these studies [5, 14, 25, 26, 28, 30, 32, 34-36, 38, 39, 43], most of them (39.1%, n=9) reported primary healthcare and FHS as determinant factors for infant mortality [5, 14, 28, 30, 32, 35, 36, 38, 43].

Healthcare policies and actions

The creation of the SUS and the implementation of the FHS were important factors to reduce infant mortality [30, 32, 35, 36]. The decentralization of resources and autonomy in decision-making at the municipality level and greater availability of primary care physicians were also important for reductions in IMR [38, 43]. These strategies also allowed the interaction of actions for substantial reductions in U5MR on a national basis, such as healthcare promotion [14] and immunization [28, 39]. On the other hand, decentralization and autonomy led to chronic underfunding, revealing the incapacity of small municipalities to provide access to adequate health by hiring healthcare services from the private sector to prevent IMR [25].

Disparities in the degree of implementation of the SUS among regions and its effects on IMR [34] and U5MR [32], in addition to the rise of private health insurance coverage as a factor contributing to reducing IMR [38] raise questions about the lack of comprehensiveness and quality of public healthcare.

Global governance over health actions aiming at reducing infant mortality were also important factors influencing U5MR. Brazil and other countries that followed the Millennium Development Goal Guidelines to reduce U5MR by two thirds between 1990 and 2015 (MDG-4) have attained the MDG-4 target ahead of schedule. These countries also followed protocols and guidelines of the Community Case Management program (CCM) proposed by the WHO for treating pneumonia and diarrhea [26].

Policies not directly related to health

65.2% (n=15) of papers reported the outcome of social and economic policies as factors associated with infant mortality [5, 8, 24, 25, 27-34, 36, 38, 43]. Most articles (39.1%; n=9) refer to the influence of socioeconomic conditions [5, 24, 28, 29, 31-34, 38] on the effectiveness of health policies or living conditions associated with infant mortality.

At this point, we must define the concept of socioeconomic condition according to these studies such as income, education and employment. Some studies associated the reduction of infant mortality with the reduction of social inequalities [5, 28, 29]. Although macroeconomic policies in Brazil, such as the currency stabilization plan called *Plano Real* and minimum wage policies, had led to reductions of PMR [33], socioeconomic inequalities persist [31-33] and were barriers to the use and effectiveness of the health system and policies to reduce infant mortality [5, 24, 34, 38]. Economic growth [22] and general development were pointed out as the main forces in determining better health conditions to prevent IMR [42].

A longitudinal study investigated the temporal and spatial evolution of socioeconomic inequalities on the decreasing trend in child (under-five) and infant (under-one) deaths. The results revealed that over the study period, the concentration index for deaths of children under-five from mothers with low schooling was greater than for the deaths of children under-one from mothers in the same schooling bracket. That study also found great variability of income related to infant and child mortality, with low concentration indexes at the end of the period, suggesting that income inequalities impacted infant and child deaths to a lesser extent over time [29].

The Brazilian Conditional Cash Transfer *Bolsa Família* Program

Many studies reported BFP as a factor impacting infant mortality [8, 28, 30, 33, 36, 38, 43], accounting for 30.4% (n=7) of the macro-environment. If, on the one hand, the FHS expanded the supply of primary healthcare, on the other, the PBF boosted the demand for the use of those services [8, 30, 36].

A longitudinal study covering 1998 to 2010 stressed that FHS effectiveness strongly depended on the expansion of the BFP to reduce PNMR and that the increased usage of prenatal care services was greater in the Northeast than in the other regions. The author, however, raised the possibility that the programs may have been implemented in places where decreases in PNMR were already underway.[30]. This possibility is in line with the results of a cross-sectional study that found that infant mortality (IMR) was already declining in the decades leading up to the implementation of the BFP, although the program was associated with further declines in IMR and PNMR [8].

A panel data study on the effects of BFB on U5MR also showed that the program had important effects on nutrition and the reduction of deaths from diarrhea between 2004 and 2009. In addition to finding statistically significant association between BFP coverage rates and U5MR, the study also found a statistically significant relationship between per capita income and U5MR. The study

demonstrated that between 2004 and 2009, per capita income increased by 46.5% while under-five mortality decreased by 19.4%, from 21.7 deaths to 17.5 deaths per thousand live births [36].

Findings also suggest that economic development and interventions in the national health system on proximal terms could lead to short-term gains, but sustainable declines in IMR depended primarily on better quality and accessibility to prenatal care [43]. The socio-environmental policy was reported in one study, stressing the association of basic sanitation services, such as garbage collection, with infectious diarrheic diseases and IMR [27].

External dimension 2 – Access and effective use of the health service system

The access and effective use of health services associated with infant mortality was found in 78.3% (n=18) of studies [5, 8, 14, 20, 24, 25, 28, 30, 32-41, 43]. The association of the reorganization of health services and infant mortality [5, 8, 24, 25, 28, 30, 33-38, 41, 43] was reported in 60.9% (n=14) of studies, while access to services [8, 24, 25, 32, 33] and quality of healthcare [14, 24, 30, 41, 43] both were reported in 21.7% (n=5) of papers. With regard to the health categories that were associated with infant mortality, the most frequently cited were prenatal care [28, 30, 33, 36, 41, 43] (26%; n=6), vaccination [28, 39] (8.7%; n=2), and information system [34] (4.3%; n=1).

Coverage, reorganization and access to health services

Papers reported the association of increased coverage of primary healthcare provided by the FHS with reductions in IMR [38] and U5MR [35], especially by preventable causes such as infectious diarrheic diseases [5]. Studies also demonstrated that higher coverage of the FHS and improvements in primary healthcare were associated with reductions in PNMR [30], IMR [8, 43] and U5MR [28, 36], also contributing to reducing health inequalities. As mentioned in the analysis of dimension 1, one study associated private health insurance coverage and declines in IMR [38].

The studies found that IMR is affected by the fact that health service facilities were concentrated in capitals, urban and central areas, which led to a significant disparity in providing health services to the rural, peripherical and poorest areas [24, 34]. One study reported disparities among macro-regions related to the distribution of public health services and NMR [37].

Although many studies reported increasing coverage of programs allowing access to primary healthcare, inequalities remained and deficits in primary care redirected patients to emergency services and unnecessary hospitalizations, leading to mismanagement of cases relating to IMR and U5MR [32]. This also led to high rates of unnecessary cesarean sections and neonatal mortality

[41]. One study also related the availability of neonatal intensive care beds with neonatal mortality [33].

Underfunding and economies of scale in a context of universality and equity of access was quite challenging for small municipalities, contributing to infant mortality. Decentralization posed financial strain for municipalities with higher per capita health spending due to difficulties in raising funds. This also created difficulties in recruiting, retaining doctors, and hiring medium- and high-complexity procedures from the private health sector, leading to gaps in the comprehensiveness of services and increases in IMR [25]. One study on post-neonatal mortality concluded that in addition to increased access to primary care, the quality of hospital care was one of the most important factors influencing PNMR [30].

Quality of services

Quality of services was investigated in six papers. The studies reported that approximately 70% of IMR are determined in the neonatal period, linking these deaths to the quality of prenatal care that is affected by gaps in the access to healthcare facilities [38] and that the evolution of childbirth in Brazil between 1993 and 2013 was likely related to problems of hospital quality and antenatal care. Over this period, increases in the coverage of antenatal obstetric care and prenatal consultations were observed simultaneously with increases of preventable infant deaths (PMR and IMR) linked to adequate assistance and care during childbirth [41]. Studies also reported that PNMR associated with complex cases depended strongly on referral structures [30] while adequate neonatal care could prevent death from neonatal respiratory disorders through adequate diagnosis and therapeutic actions [14].

Although this might be questionable as a quality dimension, one study related the geographic access to childbirth services to an unequal provision of quality health services as a component of maternal and child vulnerability. This, together with the lack of interaction between outpatient care and assistance for childbirth, resulted in inadequate care, lack of effectiveness, poor outcomes and increasing IMR [24].

One study evaluated the coverage and quality of the FHS and BFP based on the continued evaluation strategy program PMAQ (National Program for Improving Access and Quality of Primary Care). This program was developed under Donabedian's triad for assessing health services quality: infrastructure, work process and patient's evaluation of the service [44, 45] This study aimed at identifying how aspects of FHS quality moderated outcomes under the influence of BFP.

The conclusion was that primary healthcare provided by FHS and driven by the PBF conditionalities that most contributed to declines in IMR were planning, city government support, social participation and school health. It was also confirmed that although prenatal care was a protective factor, deaths were linked to the quality of childbirth care. The research also emphasized that the prevention of infant mortality depended strongly on the preventive suggestions provided to families by the FHS teams and on the incorporation of these guidelines in seeking care at the appropriate time [43].

As a summary of the findings related to external dimensions 1 and 2, many improvements emerged with the implementation of the SUS, such as decentralization of services and resources that created autonomy in decision-making among states and municipalities [38, 43]. Simultaneously, even under the effect of the FHS and BFP that intervened in both the supply and demand side of primary healthcare [30], decentralization led to deficiencies in the provision of health services among regions. The difficulties for small municipalities to hire private health services to close gaps in the provision of public services [25], coupled with a rise of private health insurance coverage and the availability of physicians both associated with reductions in IMR raise questions about shortcomings in the access and comprehensiveness of public health services [38].

The increasing coverage of FHS accounted for important reductions in IMR [38] and U5MR [35], mainly due to preventable causes such as diarrheic diseases [5], but deficiencies in the organization of health services, mainly in the distribution of maternal, child and obstetric care, remained as marked inequalities between urban and rural regions [24, 34]. The quality of health services was also a matter of concern, since, paradoxically, increases in the coverage of antenatal obstetric care and prenatal consultations were associated with increases of preventable infant deaths (PMR and IMR) linked to adequate assistance and care during childbirth [41].

Socioeconomic conditions also represented important factors impacting infant mortality, through income, education and employment [5, 28, 29], although income inequalities had a lesser influence on infant mortality over time [29]. Even though macroeconomic policies had led to reductions of PNMR [33], socioeconomic inequalities have remained as barriers to the effectiveness of the health system [31-33] and policies to reduce infant mortality [5, 24, 34, 38].

Intermediate dimension – Living conditions, social and life contexts

A relevant proportion of 78.3% (n=18) of the studies focused on living conditions, social and life contexts, and infant mortality [8, 24, 25, 27-36, 38-41, 43]. Many studies related income,

employment, poverty, nutrition, housing and basic sanitation to infant mortality [24, 25, 27-36, 38-40, 43], accounting for 69.6% (n=16) of studies. Maternal education accounted for 15.8% (n=3) of articles [29, 33, 40], while 8.7% (n=2) of papers associated housing location and distance with prenatal and childbirth services facilities [8, 24] and cultural differences [24, 32] to infant mortality. Only 4.3% (n=1) of papers reported maternal religious involvement [42].

Income

The relation between per capita income and infant mortality was found in many studies [24, 27, 29, 30, 33, 35, 36, 38]. The distances between housing and maternal and child healthcare were inversely related to household per capita income, revealing low income as a driver of health inequalities linked to IMR [24]. Studies related reductions of income inequality to declines in U5MR [28, 29, 35, 36], IMR [38] and NMR [33].

Housing

Papers associated U5MR with adequate basic sanitation [28] and access to clean water with PNMR [30] and U5MR [35]. Garbage collection and piped water were associated with IMR [38], while declines in IMR were positively associated with the limited access to basic sanitation services [27, 34]. A study found a positive association between sewage service coverage and IMR, although the authors stressed that this association might be due to multicollinearity between household variables [38]. Another paper reported a negative association between infant mortality and per capita health spending through municipalities' own revenues, suggesting that the ability of municipalities to raise health expenditure also led to improvements in living conditions [25].

Nutritional status and poverty

The studies found that living conditions, social and life context may affect infant mortality due to diarrhea through nutritional status [27, 28, 36]. An association was found between IMR and dependency ratio (the proportion of people between 0 and 14 years old and/or 60 years old or over in relation to the total number of people between 15 and 59 years old living in a micro-region) [27, 34]. Findings suggested that the elderly were responsible for the children and/or were providers of the very few financial resources of the household, most resulting from social benefits, which could lead to malnutrition and diarrhea [27].

Educational attainment

Some papers reported education as inversely related to PNMR [30, 34] and IMR [36, 40]. Maternal education was as inversely related to U5MR [29, 39]. In a study linking education to NMR, it was reported that the greater the access to healthcare among social groups of higher income, the higher the schooling level and access to public services (such as water, electricity, sewage and garbage collection services). Higher schooling level also favored a better perception of health and knowledge about the different medical specialties available for the treatment of diseases [33].

Fertility and religious involvement

Studies also reported an association between decreasing fertility rates and decreasing infant deaths [30, 35, 36, 41]. In a particular study, the fact of a woman giving birth to two or more children was associated with an increased risk of IMR. This study also established a negative relation between IMR and maternal religious involvement. It is worth noting that this association was established under an uncommon degree of statistical significance ($P < 0.1$) [42].

Living conditions and development indexes

Socioeconomic and living conditions indexes such as the Human Development Index (Wang et al.) [43] and Municipal Human Development Index (MHDI) [31] were associated with reductions in IMR. One article used a Family Development Index (FDI) as a multifactorial living condition indicator, aiming at assessing social inequalities associated with infant mortality among geographic areas and municipalities according to 1. presence/absence of children, adolescent, and young members, and physical and/or socially handicapped members (a dependency ratio proxy); 2. access to knowledge (formal and non-formal education); 3. Access to employment (remunerated or not); 4. availability of financial resources (per capita family income above the poverty line); 5. infant and young child development (child labor, education access and performance, and child mortality) and 6. housing conditions (number of residents, access to goods and services, including sanitation services). An association was found between municipalities according to a gradient of FDI strata and increases in IMR [34].

The results relating to the intermediate dimension stressed the importance of factors linked to the living condition such as important social determinants of infant mortality. In addition to income as an important factor for increasing nutritional status, income inequalities also played an important role as a driver of inequalities in the access to healthcare because of an uneven provision of maternal and childcare [24]. Access to employment [34], adequate sanitation and access to clean

water [35] were pointed out as factors influencing infant mortality as well. Higher educational attainment was identified as an element favoring a better perception of the health and knowledge about the treatment of diseases [33]. Finally, the fertility rate was also identified as a factor influencing infant deaths [30, 35, 36, 41].

Internal dimension – Individual characteristics/genetic and biological factors

Individual characteristics were found in 26% (n=6) of papers [8, 14, 28, 33, 40, 41]. 8.7% (n=4) of papers relating low birth weight (LBW) to infant mortality [14, 33, 40, 41], while congenital malformations [8, 28, 34, 46] accounted for 15.8% (n=3). Maternal age [14, 33, 40] is also present in 15.8% (n=3), while prematurity [14, 28] accounts for 8.7% (n=2) of the papers and an analysis of age at deaths [5, 28, 37, 38] was conducted in 8.7% [n=4] of papers.

Low birth weight, maternal age and congenital malformations

Prematurity and LBW were associated with an increased risk of U5MR [14]. In addition, a study on LBW trend identified that from 1995 to 2007 higher LBW and lower IMR were observed in more developed regions when compared to less developed regions of the country. In fact, an epidemiological paradox was reported involving LBW, maternal age and schooling [40]. There was an "age effect" regarding maternal schooling. LBW was associated with low quality and health inequalities related to prenatal care, excessive medical interventions and increases in premature birth [41]. Paradoxically, maternal age equal to or over 35 years in more developed contexts was associated with LBW and with low mortality rates. In these contexts, many women in this age bracket had a higher educational level and access to qualified jobs, better income and access to better healthcare [33]. On the other hand, in underprivileged populations, maternal age equal to or over 35 years increased the risk of LBW and early neonatal mortality were both associated with low education and biological factors. In short, maternal schooling could hide an effect of socioeconomic condition on maternal age [14]. Thus, in less developed regions, higher rates of LBW were associated with higher rates of infant mortality, while in more developed regions higher LBW rates were associated with lower infant mortality rates. Access to better healthcare, interrupted pregnancy and high rates of cesarean sections may also explain the low birth weight paradox (LBWP) [33, 40].

Congenital anomalies [28] and malformations were also reported in association with prematurity [34] and NMR [8]. Congenital malformation was observed as an increasing cause of infant deaths

in the states with lower infant mortality rates, approaching the infant mortality profile of high-income countries [28].

Infant mortality by age

Finally, with regard to the different infant mortality indicators, 52.2% (n=12) of the studies adopted the infant mortality rate [24, 25, 27-29, 31, 32, 38, 40-43], whereas 43.4% (n=10) of articles applied under-5 years child mortality rate [5, 8, 14, 26, 28, 29, 32, 35, 36, 39]. 30.4% (n=7) of the studies adopted neonatal mortality [8, 28, 30, 33-35, 41] and 21.7% (n=5) post-neonatal mortality [8, 28, 30, 34, 35]. 8.7% (n=2) of studies adopted early and late neonatal mortality rate [28, 37].

One study reported that although declines in IMR were observed between 2000-2011, early NMR remained high at the end of this period [5]. Another study related a U5MR decline from 1990 to 2015, in addition to important changes in the proportions of deaths by age over the period [28]. In 1990 the PNMR represented about 44% of U5MR, followed by ENMR and LNMR. In 2015, the ENMR was the main component of U5MR, followed by PNMR and NMR. A trend of the increasing prevalence of ENMR over LNMR was observed in another study as well [37]. IMR represented approximately 90% of the total U5MR in 2015 [28], whereas, in 2012, NMR represented more than 69.3% of IMR [38]. In recent years, although the states in the North and Northeast macro-regions experienced greater declines in overall infant mortality, disparities remained fairly high in those macro-regions [28, 37]

The main findings related to the internal dimension emphasized that the LBWP draws attention to the possible causal association between age and maternal education, and neonatal mortality. These factors must be analyzed very carefully, given the regional disparities observed regarding the association between low birth weight and neonatal mortality [14, 40]. It is worth noting the importance of NMR and IMR in the composition of U5MR. Infant deaths under-one year represented more than 90% of total deaths under-five years, while the deaths before the first 28 days of life represented almost 69% of deaths of this same period.

2.1.4 Discussion

The objective of this review was to identify and summarize the determinants of infant mortality in Brazil under the influence of social and health policies, with a view to raising hypotheses for the recent changes in the infant mortality rate and identifying gaps in research concerning such determinants.

The findings suggest that although the implementation of the SUS, the FHS and BFP have proved to be important infant mortality reducers, this review has found some limitations relating to inequalities in the access to quality and comprehensive health services that seem to have important implications for reducing infant mortality rates. Socioeconomic conditions and health-related factors interacting in the four dimensions of the CMHC such as income, educational attainment, fertility rate, housing, access to healthcare, and the BFP coverage rate were pointed out as the main determinants of infant mortality. Likewise, recent changes in infant mortality in Brazil are likely related to changes in those factors. This study also shed light on the limited capacity of social and health policies in promoting sustainable reductions in infant mortality in Brazil, mainly in the presence of socioeconomic inequalities. We also identified a gap in terms of studies on a possible direct association between employment and infant mortality.

Regarding external dimension 1, related to the macro-socioeconomic and political environment, although we do not suggest any hierarchical relationship between the four dimensions of the CMHC, State actions seem to act as an umbrella to foster macrosocial, economic and political environments that may favor or block the creation of opportunities (capabilities) for seeking health (health agency) [18]. In an attempt to clarify the boundaries of health capabilities, Tengland states that basic governmental responsibilities are health, education and creating work opportunities [47]. The FHS has improved the provision of healthcare, operating as the gateway to public health services, while the BFP has acted as a booster for the effective use of such services, through monetary incentives in exchange for the accomplishment of health and educational conditionalities [8, 30, 35, 36]. Another aspect to be considered is that the conditionalities of the BFP may raise questions about conditional cash transfer programs as an imposed obligation to deprived populations, instead of a capability. Tengland also stresses that Sen's political liberal perspective about capabilities defends the individual's freedom of choice with no interference of others, mainly the Government [47]. In fact, the BFP fosters freedom, once the financial support for families prevents child labor, given that one of the program's conditions is that payments are suspended if there is any evidence of child labor in the beneficiaries' household [48]. In this sense, Nussbaum states that basic capabilities imply a decent degree of health and primary and secondary education, at least when one comes of age. Further, some kinds of functioning are defensible, like compulsory education, as a necessary prelude for adult capability [19]. The logic of the BFP is to interrupt the intergenerational cycle of poverty by providing a minimum regular source of income to poor

families conditioned on their investing in the health and education of their children and reducing infant deaths attributable to poverty-related causes, such as malnutrition and diarrhea, which is in line with the reasonings behind the capabilities approach [36].

Still, regarding external dimension 1, Shei draws attention to the fact that policymakers should pay special attention to the adequacy of basic health services to ensure that they respond to the increased demand created by the BFP [8]. According to Vieira-Meyer, the creation of the SUS decentralized the allocation of resources of the FHS which had led to great autonomy on decision-making for states and municipalities, improving the performance of those municipalities that have incorporated planning and organizing as regular activities in the healthcare provision process according to specific goals [43]. On the other hand, decentralization resulted in financial pressure and budget inequalities and deficiencies in healthcare provision among regions, mainly among small municipalities [25], revealing shortcomings in the access and comprehensiveness of public health services, affecting infant mortality [38].

In dimension 2, related to the effective use of the health service system, results suggest that inequalities imposed limitations on the access to quality, comprehensive and adequate health services, limiting the opportunities for seeking health once they cancel the internal features of a person that are not part of health, but determine the degree of freedom for seeking health, such as self-knowledge, skills and competences [47]. Such limitations in health services access were related to deficiencies in the reorganization of services, especially regarding the distribution of maternal, child and obstetric care, boosting drivers of health inequalities that increase child mortality, especially in the North and Northeast regions of the country [24, 34].

Quality also emerges as one of the limiting factors linked to the effectiveness of health services to reduce infant mortality. Increased coverage of antenatal obstetric care and prenatal visits together with increased preventable infant deaths raised concerns about the quality of service delivered [41].

Despite improvements in socioeconomic conditions such as income, education and employment that had favored infant mortality declines [5, 28, 29], socioeconomic disparities have remained as barriers to the effectiveness of the health system [31-33] and policies aiming at reducing infant mortality [5, 24, 34, 38]. Such socioeconomic inequalities also highlighted the fact that infant mortality depends on the availability of primary care physicians and access to private health

services [38], but also hospital quality [41, 49], suggesting that maternal and infant health services in Brazil still retains some characteristics of a hospital centered model.

According to Nussbaum, a fundamental question related to the capabilities approach to be posed is: "What is each person capable to do and to be in terms of opportunities?" [19]. As factors related to the life circumstances in the intermediate dimension of the CMHC influencing infant mortality, our findings indicate that income appears as a crucial element for increasing nutritional status [27, 28, 36], but, as already mentioned, also as an antidote against inequalities in the access to health services because of an uneven provision of maternal and child care [24]. Our results associated infant mortality with a composite family index that encompasses the access to employment [34], adequate sanitation and access to clean water [35], education achievement [33] and fertility rate [30, 35, 36, 41] as part of a multi-dimensional holistic conception of health capabilities, as defended by Tengland [47].

In this review, we also identified a gap in terms of studies about a possible direct effect of employment on infant mortality. Few studies have addressed the relation between employment and unemployment and infant mortality in Brazil. In a study using panel data over populational health and economic downturn in Latin America, Williams *et al.* [46] reported that unemployment is strongly related to under-five mortality. Although the study informed that unemployment data in Brazil were not available for the study period (1981 to 2010). In a mixed study with data based on interviews collected in a small town near São Paulo, Ventura *et al.* [50] concluded that among adults living in the same household, the fact of having a job or not was an important factor in determining the degree of stability and vulnerability of families.

Taking into account the results regarding the two external dimensions and the intermediate dimension, we found that the use of health services in Brazil is unequal, with greater access to health services in the social groups of higher income, as well as greater educational achievement, greater access to public services (water, electricity, sewage and garbage collection) and supplemental health insurance [33]. Our results reinforced the intersectoral perspective of the CMHC, since the factors identified as relevant for infant mortality, such as socioeconomic conditions, interacted through all the four dimensions, although they were effectively "converted" capabilities as experienced health (health functioning) and opportunities for seeking health (health agency) at the individual level.

As individual characteristics related to the internal dimension, the LBWP [33, 40] summarizes one of the many faces of socioeconomic inequalities, such as educational attainment, employment and income may reinforce health inequalities that may impact maternal and infant health. Age and education may act as confusion factors, hiding an income effect on infant mortality as a facilitator for the access to quality maternal and childbirth services. Studies carried out in different Brazilian regions show that mothers belonging to socially more vulnerable groups receive substandard prenatal care [33]. In this sense, maternal education and its relation to maternal age should be used with caution when assessing the social determinants of health in specific socioeconomic contexts. On the other hand, studies also emphasized that the prevention of infant mortality depended strongly on the preventive suggestions provided to families by the FHS teams and on the incorporation of such guidelines in the search for care at the appropriate time [43], which suggests that a minimum degree of educational attainment at the household level is expected for reducing infant mortality.

What emerges from the literature suggests that although the 1988 Constitution defined the basis for socioeconomic development based on the development of human capital supported by inclusive social and health policies, inequalities in the access to quality and comprehensive healthcare remain as a critical factor influencing infant mortality that also depends on the access to private health services. Regarding the recent changes in infant mortality in Brazil, it is probably due to changes in income, educational attainment, fertility rate, housing, the access and the quality of healthcare, coverage of BFP, among other multifactorial determinants of infant mortality in Brazil. More quantitative studies are needed to assess the impact of those determinants on infant deaths.

Strengths and limits

This study has several strengths. To our knowledge, this is the first study to make use of the health capabilities approach in a scoping review on the determinants of infant mortality. The second strength lies in the fact that this is the first scoping review on the determinants of the different infant mortality indicators gathered in a single study. One limitation of this study refers to the possibility of weak external validity due to the specificities of the context of an upper-middle-income country. Although the World Bank [51] classifies Brazil as upper-middle-income, the country ranks only 73rd in per capita income. Another aspect that must be considered when interpreting our findings refers to the fact that the original version of the CMHC was conceived

aiming at conceptualization and operationalization of health interventions at the individual level. Our adapted version of this framework considered the specificities of the Brazilian socioeconomic context under the influence of social and health policies aiming at identifying the determinants of infant mortality at the aggregate level. Finally, due to the broad scope of the topic addressed, this study limited the analysis to quantitative studies only. This can be a source of selection bias in relation to the absence of qualitative studies aimed at identifying the variables acting within the intermediate dimension of the CMHC.

2.1.5 Conclusion

The findings suggest that although the implementation of the SUS, the FHS and BFP have proved to be important infant mortality reducers, this review has found some limitations relating to inequalities in the access to quality and comprehensive health services that seem to have important implications for reducing infant mortality rates. Socioeconomic conditions and health-related factors interacting in the four dimensions of the CMHC such as income, educational attainment, fertility rate, housing, access to healthcare and the BFP coverage rate were pointed out as the main determinants of infant mortality. Likewise, recent changes in infant mortality in Brazil are likely related to changes in those factors. This study also shed light on the limited capacity of social and health policies in promoting sustainable reductions in infant mortality in Brazil, mainly in the presence of socioeconomic inequalities. We also identified a gap in terms of studies on a possible direct relationship between employment and infant mortality. More quantitative studies are needed to assess the impact of those determinants on infant deaths.

Notes: 1. The first researcher was supported by CAPES Foundation (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, Ministry of Education of Brazil, Brasilia – DF 700040-020, Brazil – Science without Borders Program – proc. 12940/13-5), and by FESP (Faculté d'Études Supérieures – ESPUM – École de Santé Publique de l'Université de Montréal); 2. We hereby declare that there is no conflict of interest related to this study and funding agencies.

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State of knowledge

Many studies have been conducted aiming at analyzing the determinants of infant mortality, as well as evaluating the impact of social and health policies on the different infant mortality indicators in Brazil. Although some of these studies have contributed to the knowledge about the factors impacting infant mortality, such as socioeconomic disparities and in the access to comprehensive and quality health (Russo et al. 2019; Almeida W. da and Szwarcwald 2012), they predominantly used socioeconomic data as control variables. Some of these studies assessed the impact of the BFP and FHS on infant mortality showed some limitations regarding data on socioeconomic variables. Some of them were based on interpolated data from the Census surveys for relatively long intervals in relation to their observational window (Guanais 2013) or were based on short study periods (Shei 2013; Rasella, Aquino, and Barreto 2010b). Others restricted analysis within specific factors that influenced infant mortality, such as the impact of primary health care on infant mortality (Gomes et al. 2016; Russo et al. 2019; Rasella, Aquino, and Barreto 2010b), the quality of healthcare and coverage rate of BFP impacting infant mortality (Vieira-Meyer et al. 2019), the Millennium Development Goals Program and actions for reducing under-five years mortality (Boschi-Pinto, Dilip, and Costello 2017) or the impact of the implementation of SUS on preventable infant deaths (Malta et al. 2019). Studies also focused on the composition of municipal spending on health and child mortality (Araujo, Goncalves, and Machado 2017), human development indexes associated with infant mortality (Ramalho et al. 2013; Martins, Pontes, and Higa 2018), and socioeconomic inequalities and its association with infant mortality (Oliveira et al. 2013; Garcia and Santana 2011).

Most of these studies applied quantitative approaches without relying on any theoretical framework, restricting the analysis to statistical inferences and descriptive analysis (Verona et al. 2010; Silva et al. 2016; Silva et al. 2010; Schuck-Paim et al. 2019; Mendes, Ribeiro Hda, and Mendes 2013; França et al. 2017) rather than to attempt to identify, analyze and understand the mechanisms and logical pathways between social determinants of health (SDH) and infant mortality. Also, longitudinal studies used a portion of the total number of municipalities in the country, mainly due to limitations in the use of data at the time of the studies, or, as underlined, making use of interpolations for relatively long periods over relatively short observation windows. An additional challenge to be addressed when using data in Brazil is the operationalization of variables observed in different administrative instances over time. Infant mortality is aggregated

in different administrative instances such as communities, cities, states or regions of a country (Melo 2020). In Brazil, other socioeconomic data are only accessible at aggregated level such as unemployment and employment that are estimated and disseminated at the level of major metropolitan areas, states and the country as a whole. In addition, to use those variables, one must consider the socioeconomic disparities among the macro-regions of the country. An additional challenge when using aggregated data is the risk of falling into the ecological fallacy and producing incorrect and biased estimations.

The 26 Brazilian states and the Federal District are grouped into five major macro-regions with very distinct socioeconomic, political, institutional and cultural characteristics: North (1), Northeast (2), Southeast (3), South (4) and Midwest (5). Those socioeconomic characteristics are homogenously distributed within macro-regions (Figure 3).

Figure 3 Brazilian macro-regions (IBGE, http//ibge.gov.br)

The identification, monitoring, and analysis of epidemiological changes over time are central to informing the public policy formulation process. However, as seen, data are not always available, are of low quality, or have been collected and disseminated in insufficient periods to assist the formulation of these policies. In addition, the categorization of data by population groups such as

ethnicity, gender, or geography is often poor. Although data is necessary, they are not sufficient in themselves to guarantee the implementation of policies (Exworthy 2008).

Few studies have included theoretical frameworks as analytical tools to reviewing the social determinants of infant mortality in Brazil. Buhler, Ignotti *et al.* (Buhler et al. 2014) used a theoretical model called GEO Health (United Nations Environment Program - UNEP / World Health Organization - WHO), which guides the analysis of factors associated with the occurrence of childhood diarrhea and death, by applying a chain of dimensions (driving force, pressure, state, exposure, effect and actions), aiming at constructing indicators that characterize the relationship between environment and health. Although the study was capable of identifying clusters in the North and Northeast states with higher rates of teenage mothers, low per capita household income, less prenatal consultations and neonatal intensive care units beds as factors contributing to neonatal deaths, the results remained limited to identify areas of social vulnerability and associations between neonatal mortality and social determinants of health, without however providing a systematic analysis of the forms and logical pathways of interaction between those determinants and health outcome. Despite the study announcing GEO Health as a theoretical model, it would be more appropriate to refer to this tool as a methodology for mapping health inequalities.

Rasella, Aquino *et al.* (Rasella et al. 2013), in a mixed study, combined panel data and an ecological analysis based on data from 2853 Brazilian municipalities, aiming at assessing the effect of BFP on under-five mortality due to diarrhea. This study analyzed findings by developing a theoretical framework to explaining the mechanisms linking the BFP to child nutritional and health outcomes in a conceptual framework. Since the aim of the study was exclusively to assess the effect of BFP on child mortality, this framework did not considered the private health system, nor its impact on child mortality. Also, the framework proposed showed social, economic and political contexts as prevalent elements, acting on the other social determinants of health, although the study used socioeconomic variables based on interpolated data from the 2000 National Census as control variables.

For some decades now, theoretical frameworks of SDH have been developed and studied as an attempt to elucidate the mechanisms through which these determinants affect health and the living conditions of populations. Although they are a good starting point, those theoretical frameworks hardly adapt to local contexts and the peculiarities of SDH and rarely offer policymakers a clear direction for policy development (Melo 2020). One possible solution for this problem is to apply

conceptual models that offer new insights about SDH policy-making and the application of existing methodologies adapted to the specific characteristics of the policies related to the SDH. Together, conceptual models and appropriate methodologies can contribute to improving policy formulation which can, in turn, improve the conditions of many of the poorest worldwide (Exworthy 2008).

The conceptual model of the main determinants of health developed by Dahlgren-Whitehead in 1991, was one of the pioneering attempts in this regard. A layered structure that represents multiple levels of health determinants, with the individual as the core of this multilevel structure, having his or her behavior, the interaction with factors such as social and community networks, lifestyles, living and working conditions, among others as the main determinants of health (Dahlgren 2007). Dahlgren-Whitehead main determinants of health model were revised in 2007 and the authors addressed health equity by including health policies targeting strategies at anyone of the layers without necessarily including all of them to attaint population health improvements. In this sense, although this model considers the determinants from the layers surrounding the individual to the most distant, from living and working conditions, to the food industry, education, work environment, unemployment, water and sanitation, health service and housing, it remained heavily grounded into health interventions on health inequities as determinants of health and it did not explicitly include public policy as drivers of population health.

Another important theoretical model was developed by Evans & Stoddart which share many of the categories proposed by Dahlgren-Whitehead, that also considered other health determinants such as prosperity and wealth production (Evans 2012). As stressed by Evans & Stoddart, their conceptual model has limitations that hinder its application in empirical and causal analysis, as the entities that form the components of its framework are themselves categories, which have rich internal structures that hardly could be adequately represented by single homogeneous variables, neither subjected to mathematical or statistical manipulations, risking of capturing only some aspect of a particular category. The authors also stated that linear and causal relations are limited to the analysis of social determinants of health, as health is a dynamic and multidimensional phenomenon requiring a systemic approach. In this sense, the multidimensional nature of health also seems to indicate that there exists an additional limitation regarding the model proposed by Dahlgren-Whitehead.

Another aspect to be taken into account is the fact that these theoretical models did not consider health inequalities in developing countries as elements to be observed when trying to analyze the SDH. One must make a semantic distinction between health equity, as referred to by Dahlgren-Whitehead, and health inequality. In few words, inequity is associated with unfair preventable differences arising from poor governance and/or cultural and ethnic exclusion, for instance, while inequality refers to an uneven distribution of health or health resources as a result of genetic or other such as a lack of resources. Any measurable aspect of health that differs across individuals, social groups or populations can be considered health inequality, like disparities in mortality rates among different populations (Global Health Europe 2020; Arcaya, Arcaya, and Subramanian 2015). Thus, the model of Dahlgren-Whitehead and Evans & Stoddart seem to be more aligned with the context of developed countries, since among less developing settings cultural and socioeconomic inequalities are more easily observed and, in many contexts, both health inequities and health inequalities are part of the landscape.

Intending to fill the existing gap identified in the studies that proposed to analyze the determinants of infant mortality in Brazil within the scope of SDH, this thesis proposes the use of two theoretical frameworks. The CMHC, as the main analytical framework, used in the literature review on the determinants of infant mortality in article 1, as well in the panel data analysis of these determinants in article 3, and the theoretical framework of the WHO's CSDH, which we used as a conceptual model to perform a descriptive analysis in the article 2.

The adoption of two conceptual frameworks aims to adapt the most appropriate models to respond to our research objectives. In light of the enacting of a new Constitution, the implantation of a universal health system and social and health policies, the CMHC seems more adjusted to the identification and analysis of the determinants of infant mortality in Brazil in a multi-dimensional perspective of SDH, grounded on human rights and individual freedoms. On the other hand, the CSDH conceptual framework simplifies the analysis of regional disparities, as it breaks downs these determinants only into two major categories, as we will see in the following subsections.

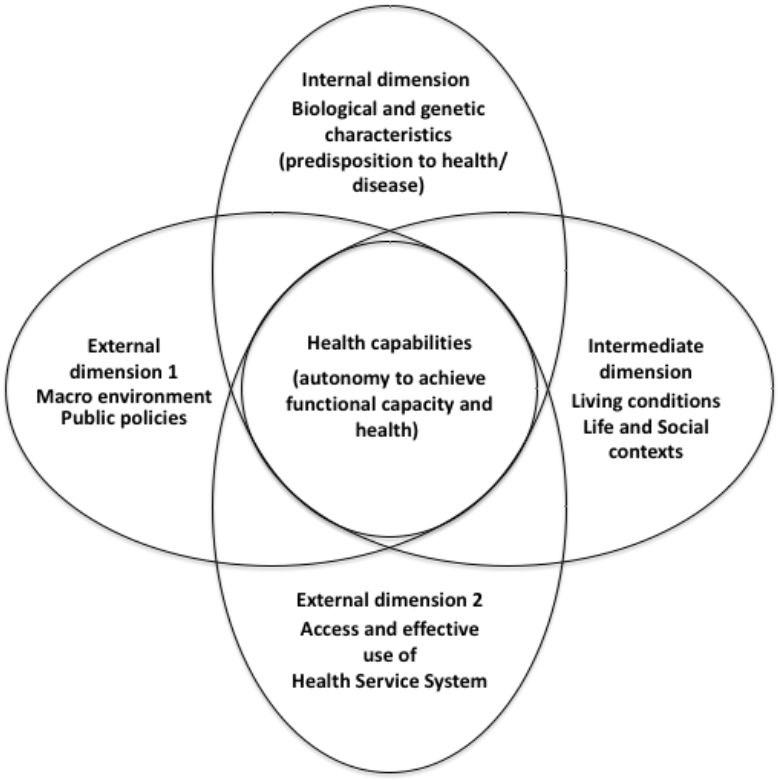
The CMHC

In 1988 Brazil enacted a new constitution that paved the way to the implantation of SUS and in the implementation of social and health policies. The Constitution established health as a human right and an obligation of the State. The constitutional's commitment to citizen’s fundamental

entitlements that ensured the right to health invokes one of the central pillars of the capabilities approach. As advocated by Nussbaum, rights require affirmative government support for their creation and preservation. From this perspective, rights would be one of the premises for an individual to achieve the substantive freedom, or the ability to perform alternative combinations of functions or the freedom to have different lifestyles (Nussbaum 2013).

Grounded in the concept of capabilities (Sen 1979, 2002), the CMHC (Figure 4) developed by Ruger (Ruger 2010), has as a core principle that individuals seek health and the ability to seek health. The CMHC considers the individual's sense of health and functional capacity for attaining health capability as the result of the interaction of four dimensions.

Figure 4 Adapted Conceptual Model of Health Capability (Ruger 2010)



Health capability results from the interaction of an external dimension related to the macro, social, political and economic environment, a second external dimension referring to the effective use of health service system, an intermediate dimension linked to social and life contexts and an internal dimension that refers to the individual's predisposition to health/disease, related to genetic and biological characteristics. The health capacity of the individual is the ability to achieve health goals that he or she considers as a value, acting as his or her own health agent (health agency) and health itself as a set of actions to maintain and/or improve health (health functioning). The CMHC

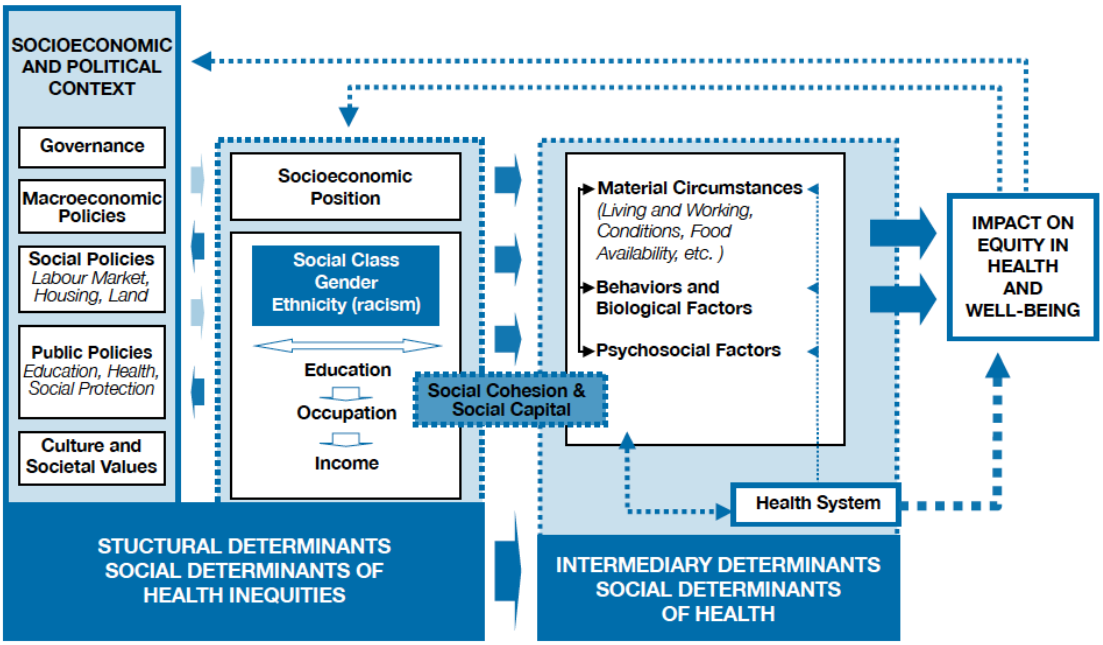
assumes that there is an almost invisible boundary between state paternalism and self-agency as a result of interactions between the four dimensions, as enablers for individuals and populations to achieve and maintain health as social and economic values.

The concept of capabilities has been pointed as an important approach to the analysis of SDH, and infant mortality has been considered an adequate indicator of the population's health attainment (health functioning), whereas determinants such as education, housing, employment and economic inequalities as social and environmental factors as conversion factors (capabilities) (Barreda R.L. 2019).

The WHO's CSDH conceptual framework

The WHO states that complexity defines health. In the perspective of public health, the WHO's Commission on Social Determinants of Health (CSDH) developed a theoretical framework that consolidated the main theoretical models on the SDH in a single framework (Figure 5).

Figure 5 WHO's CSDH conceptual framework (Solar 2010)



One of the basic assumptions of the CSDH conceptual framework is that the effects of social determinants on population health and health inequalities are characterized by a mechanism of causal chains and mediating factors. Many these factors tend to form clusters among individuals living in underprivileged conditions and interact with each other (Solar 2010).

The CSDH framework is broken down into structural and intermediary determinants. Structural determinants encompass the social, economic, and political context which determines how and where a person is born and lives, which also determines his or her socioeconomic position. Socioeconomic position influences the intermediary determinants (material circumstances, psychosocial circumstances, behavioral and/or biological factors, and the health system as a social determinant itself) and the exposure to risks. In this perspective, human rights and inequalities are closely related. The State is the promoter of health equity through public policies that also should be directed towards the reduction of health inequalities as a principle of social justice. The CSDH framework advocates that public policies may act on both by promoting the SDH and the distribution of these determinants. The bridge between the structural and intermediary determinants is social cohesion and social capital. In light of health inequities and inequalities in Brazil, the CSDH framework arises as an appropriate theoretical approach for assessing the evolution of the determinants of infant mortality in the different macro-regions of the country.

In the following subsection we demonstrate how these two theoretical frameworks were applied in the research articles 2 and 3 of this dissertation.

Chapter 3 Methods

To achieve our research objectives, we conducted two studies (Articles 2 and 3). In Article 2, we conducted a descriptive retrospective analysis of the determinants of infant mortality in Brazil between 2004 and 2015, based on the model of WHO's CSDH conceptual framework, aiming at analyzing the evolution of these determinants to understand the behavior and disparities of IMR observed in recent years in the country. In article 3, we performed a panel data analysis as a methodological proposal in order to identifying the factors impacting mortality in Brazil according to the CMHC, aiming at raising plausible hypothesis to explain the behavior ant the disparities of infant mortality observed in recent years in Brazil, after the implementation of FHS and BFP.

For both studies we used secondary aggregated data from 12 periods (years) encompassing the interval from 2004 to 2015. In the descriptive retrospective analysis in article 2 we used aggregated average values from the 26 Brazilian states grouped into the five macro-regions. In the multilevel panel data analysis in article 3, we used aggregated data from de 26 Brazilian states.

The study period for both articles was defined considering the implantation of BFP that was officially implemented in October 2003, as well as the availability and homogeneity of data regarding the employment rate.

Article 2. methods

3.1.1 Data

In this study, we used average values of secondary aggregated data of the 26 Brazilian states between 2004 and 2015, having as units of analysis the five macro-regions. The country's capital, Brasília, is a hybrid administrative instance (city-state) which presents a disproportionate per capita income when compared to other states, which may introduce bias in our models. Therefore, Brasília was excluded from our study. We calculated the average values of the data in the study by states and grouped them in the respective macro-regions of the country: North, Northeast, Southeast, South, and Midwest.

In the perspective of macroeconomic and social policies and socioeconomic class (structural determinants), income arises as a factor to be analyzed in relation to infant mortality. Education attainment, BFP coverage rate, and employment rate are also connected to social and public policies among the structural determinants related to infant mortality. The fertility rate is a proxy of behavior, as household decision and managing capacity for tackling childbearing, the access to quality and comprehensive health services, related to the health system as a social determinant

itself, and housing, through safe water supply and sewage services coverage rates are connected to the intermediary set of determinants.

Infant mortality

IMR is an indicator of population health outcome. We opted to use IMR, as 70% of this indicator consists of NMR, while IMR accounts for 90% of the U5MR. Also, IMR is widely used as an indicator of the population's health. In our study, IMR is a proxy of health outcome related to social determinants of health regarding both the structural and the intermediary set of determinants.

The structural determinants of infant mortality

1) The Real Gross Domestic Product (RGDP) per capita was used as a proxy of per capita income and it corresponded to the value of the deflated Gross Domestic Product of a state divided by its number of inhabitants in a given year and is related to the social class in the group of structural social determinants of health.

2) The coverage rate of the BFP was the proportion between the families followed by the BFP and the number of families enrolled in the program in a given year, as a proxy to evaluate the impact of social policy on infant mortality related to the structural group of determinants.

3) The educational attainment rate corresponds to the ratio between the net secondary school enrollment rate and the net primary school enrollment rate in a given year and is related to socioeconomic position also in the structural group of determinants.

4) The employment rate (the appropriate Brazilian terminology is occupancy rate) of the population was calculated using the methodology proposed by the Brazilian Institute of Geography and Statistics (IBGE), as the ratio between the total of employed persons aged 10 years or more and the total economically active persons linked to the structural group of determinants as well.

The intermediary determinants of infant mortality

5) The proportion of livebirths by the number of prenatal visits of women aged from 15 to 49 years (reproductive age) in a given year was used as a proxy of the quality of prenatal care. The higher this ratio, the better the results in terms of livebirths as a measure of the effectiveness of prenatal healthcare. This factor is related to the intermediary group of determinants related to the health system.

6) We also used the number of physicians and nurses by thousand inhabitants, which was conceived to assess the impact of the availability of health professionals on infant mortality and also as a proxy to evaluate the accessibility and comprehensiveness of healthcare. This indicator

was obtained by dividing the sum of the average number of physicians plus the average number of nurses in a given year, divided by thousand inhabitants living in a state and it is a factor related to the health system in the intermediary group of determinants as well.

7) The fertility rate was calculated by the ratio between live births in a given year and the total female population of reproductive age (between 15 and 49 years) in a given state, in a given year: The fertility rate was obtained by the ratio between livebirths in a given year and the total female population of reproductive age (between 15 and 49 years). This indicator is related to the capacity of the household to manage and tackle childbearing as a result of material circumstances and behavior in the intermediary group of determinants.

8) Safe water supply corresponds to the proportion of the total households with access to safe water supply service in relation to the total of households in a given year. These data were used as a proxy of living conditions in the intermediary group of social determinants.

9) The total sanitation service coverage rate was the proportion of the total households with access to sewage collection and treatment services in relation to the total of households in a given year. This indicator was also used as a proxy of living conditions in the intermediary group of social determinants.

Data sources

The employment rate (OCC), fertility rate (FR), school attainment rate (EDA), Real Gross Domestic Product per capita (RGDP), and the household income stratified by socioeconomic categories (IS) were obtained from the database of the Brazilian Institute of Geography and Statistics (IBGE-SIDRA database). Those data were estimated through the PNAD survey. The PNAD was conducted annually by the IBGE since 1981 and surveyed several characteristics of the population such as household structure, education, labor, income, and fertility. The PNAD sample in 2012 consisted of 147,203 households, with 362,451 residents. After 2012 the PNAD survey was transformed into PNAD Continuous on a monthly basis and in 2015 IBGE stopped publishing the annual series for employment rates.

It is worth mentioning that for the Census Year of 2010, PNAD surveys were not conducted and there were no data values in that specific year since the IBGE uses different samples and methodology for Census and PNAD. Thus, for employment (OCC), Real GDP per capita (RGDP), household income stratified by the number of average nominal minimum wages (IS_A to IS_F), water and sanitation data, total safe water coverage (WCT), sewage collection and treatment

coverage (SWT), and educational attainment (EDA) we applied linear interpolation to obtain the values for 2010. For the year 2004, there were no data available in the DATASUS for the number of families covered by the BFP and for the number of physicians and nurses (MEDEN). We used backward linear regression forecasting ("backcasting" in fact) to generate values for the number of physicians and nurses for that year. For BFP coverage specifically, as the program was implemented in October 2003, we used data only from the period when the program had expanded from 2005 to 2009 to estimate values for 2004 (Litwin, Perova, and Reynolds 2019).

3.1.2 Analysis

First, we conducted a correlational analysis, using scatterplots diagrams and Pearson's correlation matrix, based on the average values of the five macro-regions over the study period, aiming at identifying possible correlations between the infant mortality rate (IMR) and the factors related to the structural and intermediary groups of SDH Next, we made a descriptive analysis of these factors, reviewing the degree of disparities among the macro-regions. Then, we analyzed the evolution of each indicator over the period based on graphs according to the 5 macro-regions of the country. For our analysis we used the statistical software STATA® version 13.1.

Article 3. methods

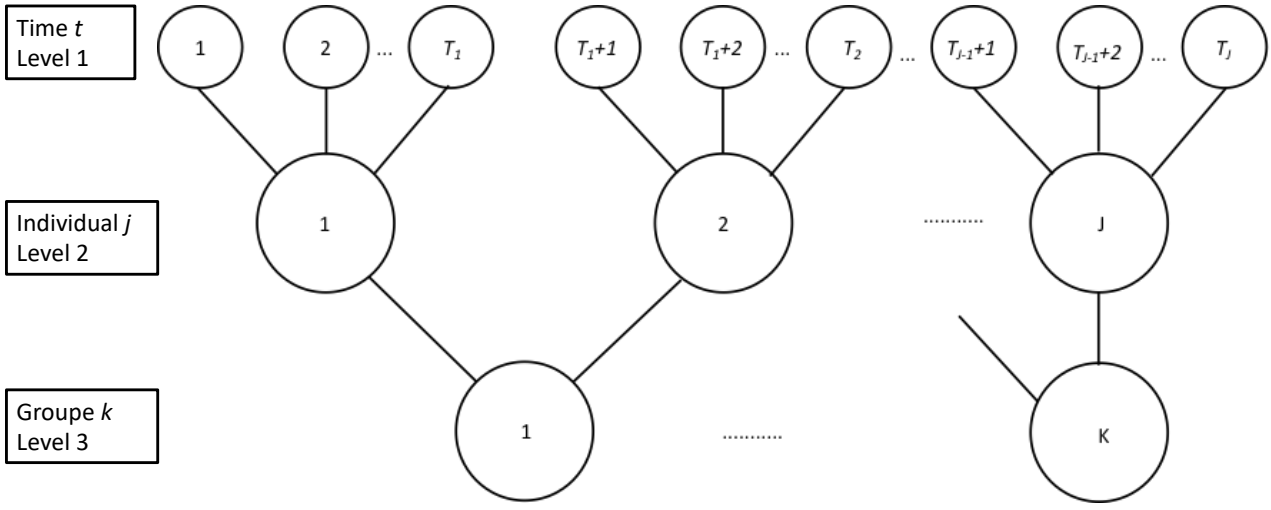
3.1.3 Panel data specifications

Multilevel panel data

From the perspective of SDH, identifying the factors affecting a health outcome requires the operationalization of variables that must fit for modeling multidimensional relations (Melo 2020; Evans 2012). To organize the possible factors acting on infant mortality among those different administrative instances over time, aiming to find statistically meaningful evidence when errors are differently distributed within and between macro-regions is a great challenge (Evans RG 2003; Melo 2020).

According to Moulton, (Moulton 1990)**,** modeling data from grouped structures based upon the assumption of independent disturbances is not appropriate. Individuals' (units) observations over time within the aggregate level, as states nested in macro-regions, are clustered and are more similar to each other than units from another cluster. In this type of data structure, clustered errors occur because unobserved factors varying over time are more homogeneous among clustered units than others and there are different levels of fixed effects within and between clusters (Cameron 2006). The statistical study with such data structure (Figure 1) requires multilevel clustering panel data (Hair 2019).

Figure 1 Three-level clustered structure with repeated measures



Reference: Hair & Favero, 2019 (Hair 2019).

In this data structure, the errors are not i.i.d. and the within-cluster errors (υ_{tjk}) may occur and are broken down in a common choke component in a given observation (ν_k, cluster-specific error) and an idiosyncratic component (ζ_{jk}), as follows:

$$\upsilon_k = \nu_k + \zeta_{jk}$$

VCE (Variance-covariance matrix of estimators)

The absence of clustering control may lead to underestimated standard errors and to overestimated statistical significance (Cheah 2009; Baum 2011). In this sense, by relaxing the assumption of i.i.d. errors, opting for a more realistic data structure that allows intragroup correlations, we should consider the use of a cluster-robust variance-covariance matrix of estimators (VCE). The VCE clustered robust estimators relax the assumption of independence of the errors and replace it with the assumption of independence between clusters.

3.1.4 Data

We created a secondary aggregated database from 12 periods (years) covering the period from 2004 to 2015 and having as units of analysis the 26 Brazilian states, distributed among the 5 socioeconomic macro-regions (Figure 4). As explained in the section Methods, the country's capital, Brasília, is a hybrid administrative instance (city-state) which holds particular characteristics that may introduce bias in our estimations, thus, Brasília was excluded from our study. The study period was defined considering the beginning of BFP that was officially implemented in October 2003, as well as the availability of data regarding the employment rate. We used the data series collected and disseminated by the PNAD. In 2012, the PNAD evolved to PNAD Continuous, on a monthly basis, and in 2015, the IBGE stopped publishing the former PNAD annual series referring to employment rates. By coding the states (id: from 1 to 26) and macro-regions (mr: from 1 to 5), we attributed categorial variables in the model to nest states (id) within-clusters (mr and years). We relied on 312 observations from 26 Brazilian states over 12 years, nested in 60 clusters (5 macro-regions times 12 years). Our dataset is balanced, implying that observations are corresponding to all units over our study period (T2 – T1 = … TJ – TJ-1).

3.1.5 Dependent variables

Our dependent variables were the neonatal mortality rate (NMR), infant mortality rate between 0 and 1 year (IMR) and infant mortality rate between 0 and 5 years. Those indicators are widely used in infant mortality studies. This will allow us to compare our results with those of other studies.

The neonatal infant mortality rate was calculated as the ratio of children who died during the first 28 days of life and those born alive in a given year: NMR= $\left(\frac{\textbf{Number of deaths during the first 28 completed days}}{\textbf{1000 live births in a given year}}\right)$

The under-one mortality rate was calculated as the ratio of children who died under one year of age to those born alive in a given year: IMR= $\left(\frac{\textbf{Number of deaths of children under one year of age}}{\textbf{1000 live births in a given year}}\right)$.

The under-five mortality rate was calculated as the ratio of children who died under 5 years of age to those born alive in a given year: U5MR= $\left(\frac{\textbf{Number of deaths of children under five years of age}}{\textbf{1000 live births in a given year}}\right)$.

The dependent variables were indicators of the population's health attainment (health functioning).

3.1.6 Independent variables

According to a scoping review based on the CMHC, we identified possible determinants of infant mortality acting simultaneously with the social and health policies implemented in the country since 2004.

1) The capabilities approach suggests that the employment/unemployment rate is one of the conversion factors (capabilities) of health functioning (infant mortality) among the factors accounting for the infant mortality rate. The employment rate (the appropriate Brazilian terminology is occupancy rate – OCC) of the 26 Brazilian states was calculated using the methodology proposed by the Brazilian Institute of Geography and Statistics (IBGE), as the ratio between the total of employed population aged 10 years or more (EP) and the total of the economically active population (EAP). We decided to use the employment rate (occupancy rate) rather than the unemployment rate due to methodological changes in the estimation and publicity of the unemployment rate in Brazil in recent decades. Also, the capabilities approach is a positively conceived concept in the sense that one of the basic capabilities is a person's freedom to be able to seek employment. The formula for the employment rate is then: OCC = $\left(\frac{\textbf{EP}}{\textbf{EAP}}\right) \times 100$.

1.a) In addition to using the annual employment rate (OCC), we used three different time lags. The variables OCC, OCC1, OCC2 and OCC3 referred to the employment rate by considering zero-, one-, two- and three-years-time lags respectively, in relation to both the dependent and other independent variables. This strategy aimed at determining to which extent the employment rate may impact infant mortality. In an econometric study on the economic fluctuations in the USA as well as infant and maternal mortality, Brenner (Brenner MH. Fetal 1973) demonstrated that in industrialized countries, the association between the unemployment rate and infant mortality can

vary between 0 and 5 years and that the optimal time lag lies between 1 and 2 years, depending on the infant mortality indicator (NMR or IMR).

2) The Real Gross Domestic Product per capita (RGDP) corresponded to the value of the deflated Real Gross Domestic Product (GDPR) of a state divided by its number of inhabitants (NI) in a given year. This variable assessed the effect of income on the different indicators of infant mortality: RGDP = $\left(\frac{\mathbf{GDPR}}{\mathbf{NI}}\right)$. Per capita income (represented by RGDP) is also considered a conversion factor related to both the macro-environment (as the result of macroeconomic management and policy) and the intermediate dimension (socioeconomic inequalities and living conditions).

2.a) We also assessed the impact of income on mortality rates stratified by the number of average nominal minimum wages as an attempt to identify income inequalities that may be affecting infant mortality indicators. This variable was calculated through the ratio between the income measured in terms of the minimum wage earned by households (MW) and the total households in the state (SH). It was stratified according to the following categories: low income: from 0 to 1 minimum wage (IS_F <1 MW); low-medium income: 1 to 2 minimum wages (1 MW <IS_E <2 MW); medium-income: from 2 to 5 minimum wages (2 MW <IS_D <5 MW); medium-high income: from 5 to 10 minimum wages (5 MW <IS_C <10 MW); high income: 10 to 20 minimum wages (10 MW <IS_B <20 MW) and very high income: more than 20 minimum wages (IS_A> 20 SM). Those variables allowed us to verify how the different income categories were associated with infant mortality rates (NMR, IMR and U5MR): IS_A to IS_ F = $\left(\frac{\mathbf{MW}}{\mathbf{SH}}\right)$.

3) The coverage rate of the PBF was the proportion between the families followed up by the BFP (FF) and the number of families to follow (FTF) in a given year. The coverage rate was applied to assess the effect of a macro-environment-related social policy on the different infant mortality indicators: BFP = $\left(\frac{\mathbf{FF}}{\mathbf{FTF}}\right) \times 100$.

4) The fertility rate (FR) was the ratio between live births (LB) in a given year and the total female population of reproductive age (between 15 and 49 years) (FPRA). This variable was a control variable: FR = $\left(\frac{\mathbf{LB}}{\mathbf{FPRA}}\right) \times 1000$.

5) The variables concerning safe water supply (5) and sewage services were used to evaluate housing and living conditions as factors of the intermediate dimension impacting infant mortality rates. The safe water supply coverage rate (WCT) corresponds to the proportion of total households

with access to safe water supply service (HWC) in relation to the total households in the state in a given year (HS). The variables concerning sewage services and safe water supply were used to evaluate the effect of living conditions on infant mortality: WCT = $\left(\frac{\mathbf{HWC}}{\mathbf{HS}}\right) \times 100$.

6) The total sanitation service coverage (SWT) was the proportion of total households with access to sewage collection (SSC) and treatment services in relation to the total households in the state in a given year: SWT = $\left(\frac{\mathbf{SSC}}{\mathbf{HS}}\right) \times 100$.

7) The LBPRE represented the proportion of live births by the state in a given year by the number of prenatal visits of women aged 15 to 49 years (reproductive age) in the state in a given year. This variable was a proxy of the effectiveness of prenatal care. By measuring the outcome of average successful deliveries regarding the total prenatal visits, the higher this ratio the better the results in terms of live births as a measure of the effectiveness of prenatal healthcare: LBPRE = $\left(\frac{\mathbf{LB}}{\mathbf{PRE}}\right) \times 100$.

8) As an alternative to the LBPRE, we also conducted estimations using the number of physicians and nurses (MEDEN) by thousand inhabitants, which was designed to assess the impact of the availability of health professionals on infant mortality. This variable may also be interpreted as a proxy to evaluate the access and comprehensiveness of healthcare, regardless of the availability of health facilities. This variable was obtained by dividing the sum of the average number of physicians plus the average number of nurses in a given year divided by thousand inhabitants living in a state: MEDEN=$\left(\frac{\mathbf{MED+EN}}{\mathbf{1000\ IH}}\right)$

9) The educational attainment ratio (EDA) corresponds to the ratio between the net secondary school enrollment rate and the net primary school enrollment rate in a state in a given year: EDA = $\left(\frac{\mathbf{NSE}}{\mathbf{SEPL}}\right) \times 100$.

This variable is important in our conceptual framework. Like the dependent variables that measure infant mortality as a health functioning variable, EDA measures educational functioning. Both infant mortality and educational attainment are capabilities "converted" into functionings. Although in the original CMHC there are no references of educational attainment, it is reasonable to suppose that there is a connection between the development of health and educational capabilities at the household level as a result of the interaction of the four dimensions of the CMHC.

The dependent and independent variables are displayed in Table 1 according to the dimensions of the CMHC.

Table 1 Variables according to the CMHC

Health capabilities* Achieve functional capacity and health	**External dimension 1 **** Macro-environment and Public policies	**External dimension 2**** Access to health service system	**Intermediate dimension**** Life circumstances
NNM, IMR and U5MR	**OCC, RGDP and PFB**	**LBPRE and MEDEN**	**Household income strata (from IS_A to IS_F); FR; WCT; SWT and EDA**
(*): dependent variables; (**): independent variables			

For the variables already expressed in unit values, such as the number of live births by prenatal visits, the number of nurses per thousand inhabitants, the fertility rate, as well as dependent variables NMR, IMR, and U5MR, no transformations were applied. For all variables expressed in percentages, such as employment rate (OCC), the proportion of family income expressed in minimum wages (IS_A to IS_F), coverage rate of the BFP, sewage services and water supply coverage rates, we divided the percentage values by 100 to convert them also into unit values. Regarding to per capita RGDP, this figure was divided by one thousand. As those are linear transformations, they do not affect estimations, but allow a better analysis of the results.

3.1.7 Statistic model

The general panel data model for our three-level dataset structure is noted as follows:

Level 1 Period "*t*" *(repeated measure)*	Level 2 (Observation) (STATES "j")	Level 3 (Macro-regions "K")	Y_{tjk}	$X1_{jk}$	X_{2jk}	…	X_{Qjk}	W_{2K}	W_{2k}	⋮	W_{Sk}
1	1	1	Y_{111}	X_{111}	X_{211}	…	X_{Q11}	W_{11}	W_{21}	⋮	W_{S1}
2	1	1	W_{11}	X_{111}	X_{211}		X_{Q11}	W_{11}	W_{21}		W_{S1}
⋮	⋮	⋮	⋮	⋮	⋮		⋮	⋮	⋮		⋮
T_1	1	1	$Y_{T_1 11}$	X_{111}	X_{211}		X_{Q11}				
T_1+1	2	2	$Y_{T_1 1,21}$	X_{121}	X_{221}		X_{Q21}				
T_1+2	2	2	$Y_{T_2 2,21}$	X_{121}	X_{221}		X_{Q21}				
⋮	⋮	⋮	⋮	⋮	⋮		⋮	⋮	⋮		⋮
T_2	2	2	$Y_{T_2 21}$	X_{121}	X_{221}		X_{Q21}	W_{11}	W_{21}		W_{S1}
⋮	⋮	⋮	⋮	⋮	⋮		⋮	⋮	⋮		⋮
$T_{J-1}+1$	J	K	$Y_{T_{J-1}+1JK}$	X_{1JK}	X_{2JK}		X_{QJK}	W_{1K}	W_{2K}		W_{SK}
$T_{J-1}+2$	J	K	$Y_{T_{J-1}+2JK}$	X_{1JK}	X_{2JK}		X_{QJK}	W_{1K}	W_{2K}		W_{SK}
⋮	⋮	⋮	⋮	⋮	⋮		⋮	⋮	⋮		⋮
T_J	J	K	$Y_{T_J JK}$	X_{1JK}	X_{2JK}		X_{QJK}	W_{1K}	W_{2K}		W_{SK}

Adapted from: Hair & Favero, 2019 (Hair 2019).

The general statistical model specification observes the following formulation:

$$Y_{ijt} = \alpha_{ijt} + \beta_1 OCC_{ijt} + \beta_2 RGDP_{ijt} + \beta_3 BFP_{ijt} + \beta_4 FR_{ijt} + \beta_5 EDA_{ijt} + \beta_6 LBPRE_{ijt} + \beta_7 WCT_{ijt} + \beta_8 SWT_{ijt} \ldots + \upsilon_{ij} + \varepsilon_{ijt}$$

Where, "*Yijt*" is the result of the unit (scalar) at time "t", "αijt" is the intercept specific to each unit and: "*OCCijt*"; "*RGDPijt*" (or alternatively: " *IS_Aijt* "," *IS_Bijt* "," IS_C ijt "," *IS_Dijt* "," *IS_Eijt* "," *IS_Fijt*"); "*BFPijt*"; "*FRijt*", "*EDAijt*"; "*LBPREijt*"; "*WCTijt*" and *SWTijt*" are the vectors (1 x K) of the covariant which vary over time. The β's are the vectors of the coefficients and "υ_{ij} "$= \nu_k +$ ζ_{jk}, is the decomposed scalar of the clustered fixed effects and "ε_{ijt}" is the error term.

This model is in accordance with the parameters and specifications established by the "reghdfe" command of statistical software Stata©, version 13, for multilevel panel data.

3.1.8 Data sources

The employment rate (OCC), the fertility rate (FR), the school attainment rate (EDA), Real Gross Domestic Product per capita (RGDP), and the household income stratified by socioeconomic categories (IS) were obtained from the database of the Brazilian Institute of Geography and Statistics (IBGE-SIDRA database). Those data were estimated through the PNAD survey. The PNAD was conducted annually by the IBGE since 1981 and surveyed several characteristics of the population such as household structure, education, labor, income, and fertility. The PNAD sample in 2012 consisted of 147,203 households, with 362,451 residents. After 2012 the PNAD survey was transformed in PNAD Continuous at monthly basis and in 2015 IBGE stopped to publish the annual series for employment rates.

It is worth mentioning that for the Census Year of 2010, PNAD surveys were not conducted and there were no values for some variables in that specific year since the IBGE uses different samples and methodology for Census and PNAD. Thus, for employment (OCC), per capita income (RGDP), household income stratified by the number of average nominal minimum wages (IS_A to IS_F), water and sanitation data, total safe water coverage (WCT), sewage collection and treatment coverage (SWT) and educational attainment (EDA) we applied linear interpolation to obtain the values for 2010.

For the year 2004, there were no data available in the DATASUS for the number of families covered by the BFP and for the number of physicians and nurses (MEDEN). We used backward linear regression forecasting ("backcasting" in fact) to generate values for the number of physicians and nurses for that year. For BFP coverage specifically, as the program was

implemented in October 2003, we applied data only from the period when the program had expanded from 2005 to 2009 to estimate values for 2004 (Litwin, Perova, and Reynolds 2019).

3.1.9 Statistical analysis

First, we analyzed a correlation matrix with all variables to evaluate the correlation between the dependent and independent variables and the signals of those correlations in order to compare those results with the estimations (Appendix 3).

As discussed previously, our dataset structure is based on different levels of fixed effects. We opted for estimating multilevel linear regressions panel data using the Stata's package developed by Correia for Linear Models With Many Levels of Fixed Effects. By using Correia's panel data syntax for fixed effects nested within-clusters (Correia 2017) we can treat observations at different levels of homogeneity. Further, this package was developed specifically for the use in multilevel fixed effect linear models and supports two or more levels of fixed effects in a large number of clusters. Unlike the packages with fixed effects in only one level, but which can be adapted to the use in grouped observations, a great advantage of the package proposed by Correia is that it identifies multicollinearity and omits correlated variables, providing a report after the estimation. Other packages do not identify multicollinearity and deliver estimations without omitting those variables.

3.1.10 Study design

We conducted 5 sets of estimations with 33-panel data, alternating between the three dependent variables (NMR, IMR, and U5MR) and their possible association with the independent variables. In the first set, 12 panels combined the three alternatives of time lags for employment rate (OCC, OCC1, OCC2, and OCC3) to identify if the three dependent variables (NMR, IMR, and U5MR) were associated with employment rate, and, if so, what was the optimal time lag according to the specific infant mortality indicator. After identifying the best adjusted time lag for a possible association between employment and all infant mortality rates we estimated a general model using all other covariates: per capita income (RGDP), BFP coverage (BFP), the fertility rate (FR), educational attainment (EDA), total live births by the number of prenatal visits (LBPRE), water supply coverage (WST) and sewage services coverage (SWT). For the income stratified (from ISA to ISE), in the third set, we ran 18 panels combining the three dependent variables (NMR, IMR and U5MR). Finally, we conducted 3-panel models in the fourth set to compare the effect of the

availability of physicians and nurses (MEDEN) and the variable live births by the number of prenatal visits (LBPRE) in the general model to assess the effective use and access to the health system in association with the dependent variable (NMR, IMR and U5MR).

Chapter 4 Results

Chapter 4 presents the two articles that form the body of this dissertation. In article 2 we conducted a descriptive retrospective analysis on the evolution of the determinants of infant mortality in Brazil aiming at reviewing the evolution of those determinants between 2004 and 2015, with a view to understanding the behavior and the subregional disparities of infant mortality rates in recent years in Brazil. Article 3 proposes a multilevel panel data with fixed effect nested within-cluster, based on health capabilities as a methodological approach to assess and analyze the possible associations between SDH and infant mortality in Brazil after the implementation of the FHS and *Bolsa Família* Programs.

Article 2. The determinants of infant mortality and Public Policies in Brazil 2004-2015: a descriptive study

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4.1.1 Abstract

In this article we conducted a descriptive retrospective analysis on the evolution of the determinants of infant mortality in Brazil aiming at reviewing the evolution of these determinants between 2004 and 2015 with a view to understanding the behavior and the subregional disparities of infant mortality rates in recent years in Brazil. The analysis was based on the framework of the WHO's CSDH, which breaks down the determinants of health into two groups: structural determinants, which in turn is subdivided into two subsets: socioeconomic and political context, and socioeconomic position; and intermediary determinants, which in turn is also subdivided into material circumstances, behavior, biological and psychosocial factors influencing the effectiveness of the health system. Results suggest that inequalities in infant mortality observed among macro-regions in Brazil are related to disparities in the distribution of SDH such as income, BFP coverage, education attainment, employment, fertility rate and of health-related determinants such as quality

of and accessibility to healthcare and water supply, as well as sewage services. The results also suggest that these disparities impose different dynamics between the structural and intermediary determinants of health that likely limit further reductions in infant mortality, which would probably explain both the slowdown in the reduction and the tendency of IMR to remain at a relatively high level. Although our data are limited to explain a possible cause for the increase of IMR in 2016, a possible deterioration in one or more of those determinants, such as a fall in employment rate due to the economic crisis, may be pointed out as one of the causes of interruption on the trend of decline in infant mortality.

Keywords: Infant mortality, Social determinants of health, Public policies, *Bolsa Família* Program, Descriptive analysis

The Determinants of Infant Mortality and Public Policies in Brazil 2010-2020: a descriptive study

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Background: Infant mortality as a relevant indicator of population's health, social inequalities and living conditions has been fairly documented in the literature as it still represents a major challenge for public health and health systems' decision-makers in emerging countries such as Brazil. While infant mortality rates have decreased in the last 30 years, some macro-regions of the country present great variability of infant mortality rates. These disparities, together with a rise in infant mortality and under-five mortality rates, and after the country experienced a political-economic crisis, draw attention to social determinants of health. Based on data related to the factors identified as the main determinants of infant mortality in Brazil, according to the results of a scoping review, we conducted a descriptive retrospective study aiming at reviewing the evolution of those determinants between 2004 and 2015 with a view to understanding the behavior and the subregional disparities of infant mortality rates in recent years in Brazil.

Method: We conducted a descriptive and retrospective analysis of the determinants of infant mortality in Brazil between 2004 and 2015, based on the World Health Organization's (WHO's) Commission on Social Determinants of Health (CSDH) conceptual framework aiming at analyzing

the evolution of these determinants to understand the behavior and disparities of the infant mortality rate observed in recent years in the country.

Results: Results suggested that there is a correlation between infant mortality and structural determinants such as income, the *Bolsa Família* Program, education and employment, and intermediary determinants such as the number of livebirths by prenatal visits, the number of physicians and nurses per thousand inhabitants, fertility rate, safe water, and sewage service coverage rates.

Conclusion: Our study contributes to the literature by providing a comprehensive perspective of social determinants of infant mortality in light of the WHO's CSDH conceptual framework. Results suggest that inequalities in infant mortality observed among macro-regions in Brazil are related to disparities in the distribution of social determinants of health such as income, BFP coverage, education attainment, employment, fertility rate and of health-related determinants such as quality of and accessibility to healthcare and water supply, as well as sewage services. The results also suggest that these disparities limit further reductions in infant mortality, which would probably explain both the slowdown in the reduction and the tendency of the infant mortality rate to remain at relatively high levels. Although our data are limited to explain a possible cause for the increase of infant mortality rate in 2016, a possible deterioration in one or more of those determinants, such as a fall in employment rate due to the economic crisis, may be pointed out as one of the causes of interruption on the trend of decline in infant mortality. More quantitative longitudinal studies are needed to establish an association between these determinants and infant mortality rates in Brazil, as well as to understand their dynamics.

Keywords: Infant mortality, Social determinants of health, Public policies, *Bolsa Família* Program, Descriptive analysis

4.1.2 Introduction

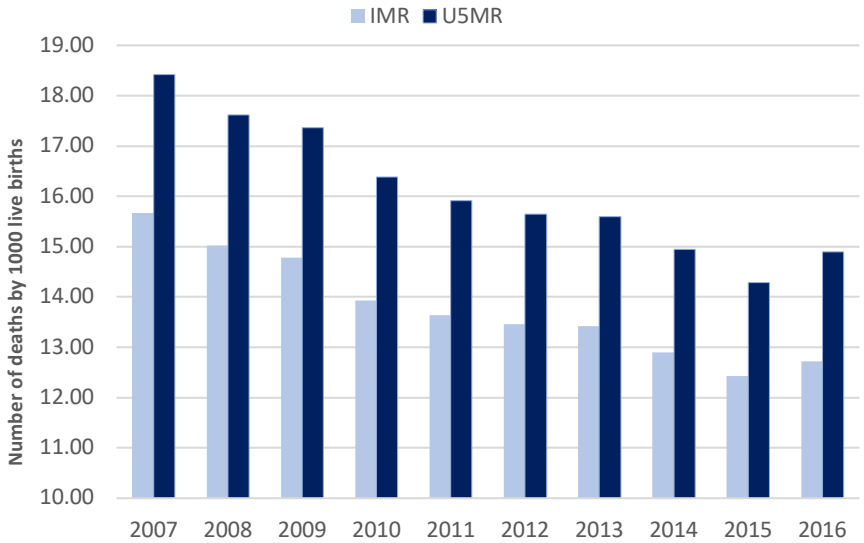
Background

Infant mortality as a relevant indicator of population's health, social inequalities and living conditions has been fairly documented in the literature [1-3] as it still represents a major challenge for public health and health systems' decision-makers in emerging countries such as Brazil. This observation gains even more relevance, considering that in the last decades, Brazil has implemented an important health program in primary healthcare, the Family Health Strategy (FHS), and a conditional cash transfer program, *Bolsa Família* Program (BFP), having as main

objectives the improvement of maternal and child health, education, and interruption of the intergenerational cycle of poverty observed in many regions of the country, that force families to prematurely putting children to work. The FHS was implemented in 1994 and focused on primary care teams that visited communities to deliver healthcare and were responsible for the health of the population of a specific geographical area [4]. In 2003, the Government implemented the BFP, aiming at providing cash transfers to families living in extreme poverty through compliance with health and educational conditionalities. The program's health conditionalities stipulated that parents should make sure that children under seven years of age comply with a growth monitoring and check-up routine and the national vaccination program. Pregnant women and breastfeeding mothers should participate in educational programs related to childcare and nutrition at their local health provider. The conditionalities linked to education required that children aged 6–17 years be enrolled in school and maintain a minimum attendance rate according to their age brackets [5]**.**

Despite all those innovative initiatives, while infant mortality rates have decreased, some regions of the country are still showing wide disparities in infant mortality rates. Such disparities, along with a rise in infant mortality (IMR: deaths between birth and 364 days of life per thousand livebirths) and under-five mortality (U5MR: deaths between birth and under five-years of life per thousand live births) after a political-economic crisis (Figure 1) draw attention to the social determinants of health as factors of great influence on maternal and child health [6].

Figure 1 Infant mortality rate (IMR) and under -five-years mortality rate (U5MR) in Brazil, 2007-2016, (SIM-TABNET/DATASUS/Health Ministry:http://tabnet.datasus.gov.br/cgi/tabcgi.exe?sim/cnv/evita10uf.def)

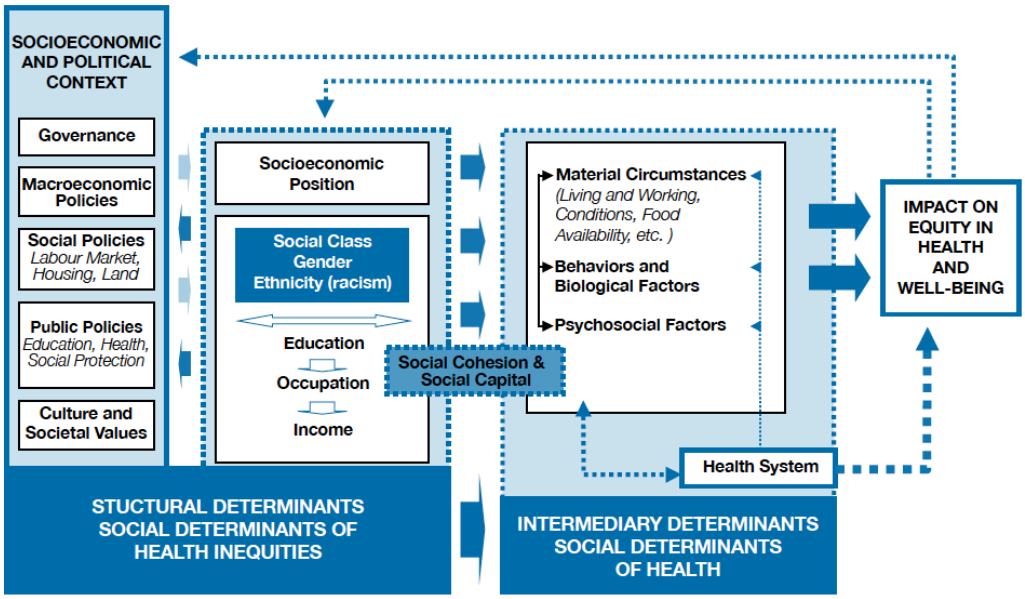


The Public Health perspective and the WHO's CSDH conceptual framework

Extensive research has been conducted aiming at elaborating theoretical and conceptual frameworks as tools capable of identifying and analyzing the SDH. One of the main models was developed in 1991 by Dahlgren-Whitehead that established the relationship between the individual, his or her environment, and his or her health. Individuals were placed at the center of the model, subjected to influencing factors that affect their health, such as lifestyle, behavior, social interaction, and living and working conditions [7]. Evans & Stoddart developed a model that also took into account prosperity and wealth production as factors impacting health [8]. Despite these conceptual models being quite comprehensive regarding the SDH, they did not include public policies as elements that could influence on health and health inequalities.

The WHO states that complexity defines health. Having this in mind and based on a comprehensive literature review on theoretical frameworks of the SDH, the WHO's CSDH consolidated a myriad of theoretical models in a single framework (Figure 2) aiming at both the operationalization of empirical studies and providing an analytical tool for public health decision-makers aiming at health actions [9].

Figure 2 WHO's Commission of Social Determinants of Health – CSDH [9]



The framework is broken down into structural and intermediary determinants. Structural determinants encompass the social, economic, and political context which determines how and where a person is born and lives, which also determines his or her socioeconomic position.

Socioeconomic position influences the intermediary determinants (material circumstances, psychosocial circumstances, behavioral and/or biological factors, and the health system as a social determinant itself) and the exposure to risks. In this perspective, human rights and inequalities are closely related. The bridge between the structural and intermediary determinants is the social cohesion and social capital. The latter is based on the notion of empowerment, having the State as a promoter of equity. In fact, the framework advocates that public policies may act on both by promoting the SDH and the distribution of these determinants.

After conducting a literature review on the determinants of infant mortality in Brazil, we identified the main factors impacting infant mortality over the last ten years. In the perspective of macroeconomic policies and socioeconomic class (structural determinants), income arises as a factor to be analyzed in relation to infant mortality. BFP coverage rate, education attainment and employment rate are also connected to social and public policies in the social structural determinants of health. Access to quality and comprehensive health services (as factors linked to the health system), the fertility rate (as household decision and managing capacity for tackling childbearing) and housing (access to safe water supply and sewage services) are related to the intermediary social determinants of health. The literature review also identified socioeconomic inequalities as a factor that may hinder the effective use of the health service system in some macro-regions of the country. This particular element is in line with the main premises of the WHO's CSDH framework.

Based on these findings, we conducted a descriptive and retrospective analysis of the determinants of infant mortality in Brazil between 2004 and 2015, building on the WHO's CSDH framework aiming at analyzing the evolution of these determinants to understand the behavior and disparities of infant mortality rate (IMR) observed in recent years in the country.

4.1.3 Methods

This was a descriptive analysis in which we analyzed the association between infant mortality and possible determinants and their evolution between 2004 and 2015. The determination of this observational window was due to the fact that the BFP was implemented in October 2003. Also, the need to isolate a period in which there was a relatively continuous series of data on socioeconomic factors determined the end of the study period in 2015.

4.1.4 Data

In this study, we used average values of secondary aggregated data of the 26 Brazilian states between 2004 and 2015, having as units of analysis the five macro-regions of the country. The country's capital, Brasília, is a hybrid administrative instance (city-state) which presents a disproportionate per capita income when compared to other states, which may introduce bias in our models. Therefore, Brasília was excluded from our study. We calculated the average values of the data by states and grouped them in the respective macro-regions of the country: North, Northeast, Southeast, South, and Midwest.

4.1.5 Data sources

The employment rate (OCC), the fertility rate (FR), the school attainment rate (EDA), and Real Gross Domestic Product per capita (RGDP) were obtained from the database of the Brazilian Institute of Geography and Statistics (IBGE-SIDRA database). Those data were estimated through the PNAD survey (National Household Sample Survey). The PNAD was conducted annually by the IBGE since 1981 and surveyed several characteristics of the population such as household structure, education, labor, income, and fertility. The PNAD sample in 2012 consisted of 147,203 households, with 362,451 residents.

It is worth mentioning that for the Census Year of 2010, PNAD surveys were not conducted and there were no data values in that specific year since the IBGE uses different samples and methodology for Census and PNAD. Thus, for employment (OCC), Real GDP per capita (RGDP), household income stratified by the number of average nominal minimum wages (IS_A to IS_F), water and sanitation data, total safe water coverage (WCT), sewage collection and treatment coverage (SWT) and educational attainment (EDA) we applied linear interpolation to obtain the values for 2010.

For the year 2004, there were no data available in the DATASUS for the number of families covered by the BFP and for the number of physicians and nurses (MEDEN). We used backward linear regression forecasting ("backcasting" in fact) to generate values for the number of physicians and nurses for that year. For BFP coverage specifically, as the program was implemented in October 2003, we used data only from the period when the program had expanded from 2005 to 2009 to estimate values for 2004 (Litwin, Perova, and Reynolds 2019).

In the perspective of macroeconomic and social policies, and socioeconomic class (structural determinants), income arises as a factor to be analyzed in relation to infant mortality. Education

attainment, BFP coverage rate, and employment rate are also connected to social and public policies among the structural determinants related to infant mortality. The fertility rate is a proxy of behavior, as household decision and managing capacity for tackling childbearing, the access to quality and comprehensive health services, related to the health system as a social determinant itself, and housing, through safe water supply and sewage services coverage rates are connected to the intermediary set of determinants.

Infant mortality indicator

Infant mortality rate (IMR) is an indicator of population health outcome. We opted to use IMR, as 70% of this indicator consists of neonatal mortality rate (NMR), while IMR accounts for 90% of the under-five mortality rate. In addition, IMR is widely used as an indicator of the population's health. In our study, IMR is a proxy of health outcomes related to social determinants of health regarding both the structural and the intermediary set of determinants.

The structural determinants of infant health

1) The Real Gross Domestic Product (RGDP) per capita was used to estimate income and it corresponded to the value of the deflated Gross Domestic Product (GDP) of a state divided by its number of inhabitants in a given year and is related to the social class in the group of structural social determinants of health.

2)The coverage rate of the BFP was the proportion between the families followed by the BFP and the number of families enrolled in the program in a given year, as a proxy to evaluate the impact of social policy on infant mortality related to the structural group of determinants.

3) The educational attainment rate corresponds to the ratio between the net secondary school enrollment rate and the net primary school enrollment rate in a given year and is related to socioeconomic position also in the structural group of determinants.

4) The employment rate (the appropriate Brazilian terminology is occupancy rate) of the population was calculated using the methodology proposed by the Brazilian Institute of Geography and Statistics (IBGE), as the ratio between the total of employed persons aged 10 years or more and the total economically active persons linked to the structural group of determinants as well.

The intermediary determinants of infant health

5) The proportion of livebirths by the number of prenatal visits of women aged from 15 to 49 years (reproductive age) in a given year was used as a proxy of the quality of prenatal care. The higher this ratio, the better the results in terms of livebirths as a measure of the effectiveness of prenatal

healthcare. This factor is related to the intermediary group of determinants related to the health system.

6) We also used the number of physicians and nurses by thousand inhabitants, which was conceived to assess the impact of the availability of health professionals on infant mortality and also as a proxy to evaluate the accessibility and comprehensiveness of healthcare. This indicator was obtained by dividing the sum of the average number of physicians plus the average number of nurses in a given year, divided by thousand inhabitants living in a state and it is a factor related to the health system in the intermediary group of determinants as well.

7) The fertility rate was calculated by the ratio between livebirths in a given year and the total female population of reproductive age (between 15 and 49 years) in a given state, in a given year: The fertility rate was obtained by the ratio between livebirths in a given year and the total female population of reproductive age (between 15 and 49 years). This indicator is related to the capacity of the household to manage and tackle childbearing as a result of material circumstances and behavior in the intermediary group of determinants.

8) Safe water supply corresponds to the proportion of the total households with access to safe water supply service in relation to the total of households in a given year. These data were used as a proxy of living conditions in the intermediary group of social determinants.

9) The total sanitation service coverage rate was the proportion of the total households with access to sewage collection and treatment services in relation to the total of households in a given year. This indicator was also used as a proxy of living conditions in the intermediary group of social determinants.

4.1.6 Analysis

Analysis

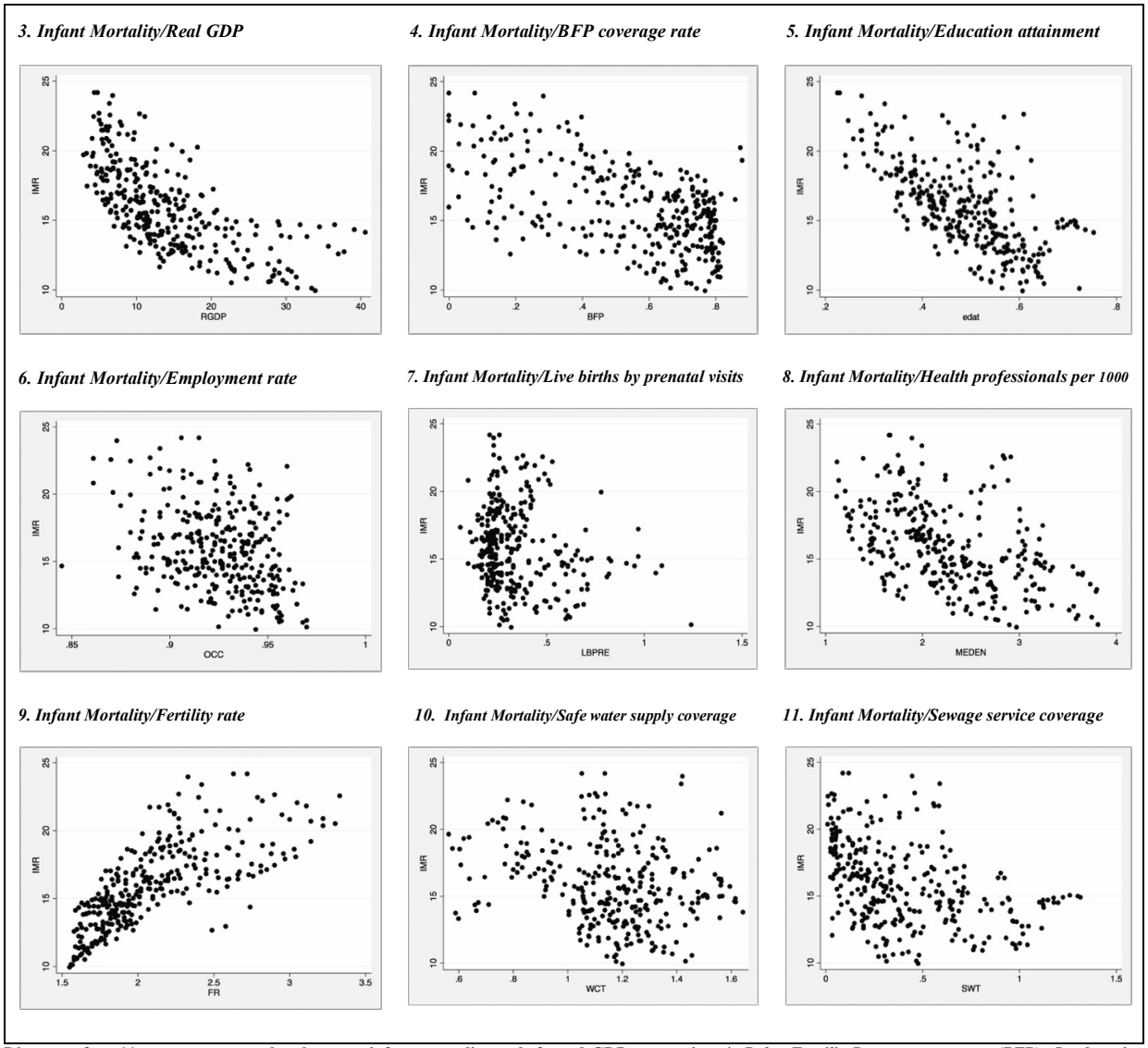
First, we conducted a correlational analysis, using scatterplots diagrams (diagrams 3 to 11 in Figure 3) and Pearson's correlation matrix (Figure 4), aiming at identifying possible correlations between the infant mortality rate (IMR) and the indicators related to the structural and intermediary groups of social determinants. Next, we made a descriptive analysis of these indicators, reviewing the degree of disparities among the macro-regions (Tables 1 to 4). Then, we analyzed the evolution of each indicator over the period based on graphs according to the 5 macro-regions of the country (graphs 1 to 10 in Figure 5). For our analysis, we used the statistical software STATA® version 13.1.

4.1.7 Results

Correlational analysis

Scatterplots (diagrams 3 to 11 in Figure 3) suggested that income represented by the per capita RGDP (diagram 3), BFP coverage rate (diagram 4) and educational attainment (diagram 5) were inversely correlated with the IMR. It is worth mentioning that the scatterplot suggests that there is a strong correlation between IMR and income which might be nonlinear and that as income increases it may have different impacts on IMR, probably more intensively on lower-income households.

Figure 3 Scatterplots diagrams 3 to 11: infant mortality/possible determinants



Diagrams 3 to 11 present scatter plots between infant mortality and: 3. real GDP per capita; 4. *Bolsa Familia* Program coverage (BFP); 5. educational attainment (ratio between the net secondary school enrollment rate and the net primary school enrollment rate-EDAT); 6. employment rate (OCC); 7. the ratio between the number of livebirths and the prenatal visits (LBPRE) 8. the proportion of the number of physicians and nurses per 1000 inhabitants (MEDEN); 9. Fertility rate (FR); 10. safe water supply coverage rate (WCT) and 11. sewage service coverage rate (SWT).

Although presenting greater dispersion, the employment rate (diagram 6), the number of physicians and nurses per thousand inhabitants (diagram 8), and sewage service coverage (diagram 11) also seem to be inversely correlated with IMR. Conversely, the fertility rate (diagram 9) was positively and strongly correlated with IMR. Highly dispersed, a possible correlation between infant IMR and the number of livebirths by prenatal visits (diagram 7) and coverage rate of water supply (diagram 10) seem unlikely.

The correlation matrix (Figure 4) suggested that IMR was negatively correlated with income (-0.67), fertility rate (0.74) and educational attainment (-0.65) and BFP coverage rate (-0.56), and positively and strongly correlated with fertility rate (0.74). Employment (-0.32), sewage service coverage rate (-0.41) and the number of physicians and nurses per 1000 inhabitants (-0.49) were weakly correlated with IMR. The number of livebirths by prenatal visits (-0.18) and water supply coverage rate (-0.24) seem not to be correlated with IMR.

Figure 4 Correlation matrix

	imr	rgdp	occ	fr	edat	wct	swt	bfp	lbpre	meden
imr	1.0000									
rgdp	-0.6682	1.0000								
occ	-0.3191	0.1500	1.0000							
fr	0.7364	-0.5998	-0.1639	1.0000						
edat	-0.6475	0.6335	0.1962	-0.4521	1.0000					
wct	-0.2443	0.0969	-0.2036	-0.3890	0.2100	1.0000				
swt	-0.4116	0.5290	-0.1888	-0.5700	0.3934	0.3663	1.0000			
bfp	-0.5640	0.3806	0.1947	-0.4390	0.3752	0.2772	0.1335	1.0000		
lbpre	-0.1843	0.4030	-0.1276	-0.1976	0.2889	0.0382	0.4112	-0.3116	1.0000	
meden	-0.4932	0.6326	-0.0145	-0.4846	0.4269	0.2911	0.4722	0.0457	0.5097	1.0000

Descriptive analysis

Tables 1, 2, 3, and 4 display the descriptive statistics of infant mortality rate (Table 1) and its structural determinants: income, BFP coverage rate (as result of social policies) (Table 1), educational attainment, and employment rate (Table 2), and the intermediate determinants: number of livebirths by the number of prenatal visits, the number of physicians and nurses per 1000 inhabitants (both related to the health system), fertility rate (Table 3) and safe water supply and sewage services coverage rates (Table 4), according to the macro-regions.

Structural determinants of infant mortality in Brazil 2004-2015

Except for the employment and coverage rates of the BFP (Table 1), the disparities observed in the structural determinants of infant mortality of the North and Northeast macro-regions are noteworthy. As shown in the correlational analysis, results suggested a strong negative correlation between per capita income (Table 1) and infant mortality, corroborated by much lower per capita

income levels observed in the North macro-region (R$ 11,963) and Northeast macro-region (R$ 8,805), both presenting the highest infant mortality rates (17.63 and 16.84, respectively). In the opposite direction, the South and Southeast macro-regions presented the highest per capita income and the lowest infant mortality rates. Although the Southeast macro-region recorded the highest average per capita income (R$22,845) and only the second-lowest average IMR in the period (13.96 deaths per thousand livebirths), conversely, the South macro-region recorded the second-highest per capita income (R$20,794) and the lowest IMR (12.09 deaths per thousand livebirths). Regarding social policies, the different results of a possible association between BFP coverage (Table 1) and infant mortality rate draw attention, since the Southeast macro-region presented the second-lowest IMR and a low coverage rate of BFP (48.96%) in relation to the other macro-regions, whereas the South macro-region presented the second-highest average coverage rate of BFP (56.67%). The highest average coverage rate of BFP was observed in the Northeast macro-region (60.24%), whereas the North macro-region recorded the third average coverage rate (51.10%).

Table 1 Infant mortality and structural determinants: Per capita income (Per capita RGDP) and *Bolsa Família* Program coverage rate

	Infant Mortality Rate*				Income (Per capita RGDP)**				*BFP coverage rate****			
	Mean	SD	CI		Mean	SD	CI		Mean	SD	CI	
North	17.628	1.64	15.53	20	11,963	3,996	6,429	16,665	51.10	23.18	6.74	71.85
Northeast	16.844	2.394	13.95	21.23	8,805	3,169	4,577	13,734	60.24	21.96	16.43	78.14
Southeast	13.958	1.247	12.39	15.86	22,845	7,414	12,329	32,707	48.96	21.81	7.77	70
South	12.097	1.377	10.32	14.77	20,794	7,379	11,491	32,297	56.67	20.43	17.52	74.89
Midwest	15.263	1.848	12.68	18.72	17,758	6,628	9,877	28,035	50.39	24.53	4.55	71.77

(*): Deaths by thousand live-births; (**): Values in Reals (Brazilian currency – R$) and (***): Percentage values

Table 2 Structural determinants: educational attainment and employment rate

	Educational Attainment*				Employment rate*			
	Mean	SD	CI		Mean	SD	CI	
North	46.24	5.53	34.7	52.85	92.42	0.669	91	93
Northeast	45.59	5.92	32.98	49.69	91.75	0.866	90	93
Southeast	56.29	2.72	52.71	59.46	91.58	1.676	89	94
South	58.76	2.35	55.47	63.41	94.83	1.029	93	96
Midwest	51.97	6.61	41.53	59.59	93.5	1.382	91	96

(*): Percentage values

The highest educational performance (Table 2) in terms of net enrollments in the secondary school by net enrollments in the primary school was also observed in the South macro-region (58.76%) and the second in the Southeast (56.29%). In contrast, a poor educational performance was observed in the North macro-region (46.24%) and Northeast macro-region (45.59%). Finally, the

South macro-region also holds the highest average employment rate (Table 2) of the series (94.83), while the Midwest presented the second-highest (93.5%) while the Southeast macro-region presented the lowest (91.58%).

Intermediary determinants of infant mortality in Brazil 2004-2015

Regarding intermediary determinants, a higher quality of prenatal care, represented by the number of livebirths by the number of prenatal visits (table 3), and greater availability of physicians and nurses (Table 3) follow the same patterns of the structural determinants, suggesting an association with lower infant mortality rates. The South macro-region recorded the second-highest average values for the number of live births by prenatal visits (0.47) and for the number of physicians and nurses per thousand inhabitants (2.77), while the Southeast macro-region recorded the highest values (5.82 and 3.02 respectively). Similarly, as observed in the analysis of the structural determinants, fertility rate also presented disparities between subregions, with a higher average number of live births by thousand women at reproductive age in the North (2.47 live births per women aged 15 to 49 years) and Northeast (2.2 live births per women aged 15 to 49 years) than in the other macro-regions. In this aspect, the South macro-region showed the lowest fertility rate (1.79 live births per woman aged 15 to 49 years).

Table 3 Intermediary determinants: live births by prenatal visits; Number of physicians and nurses by thousand inhabitants and fertility rate

	Live births/prenatal*				Physicians and nurses/ 1000 inhabitants*				Fertility Rate*			
	Mean	SD	CI		Mean	SD	CI		Mean	SD	CI	
North	0.315	0.053	0.26	0.42	2.04	0.088	1.91	2.17	2.474	0.285	2.25	3.12
Northeast	0.228	0.032	0.2	0.31	1.925	0.104	1.76	2.09	2.204	0.227	1.9	2.59
Southeast	0.582	0.117	0.38	0.85	3.018	0.203	2.7	3.28	1.807	0.126	1.64	2.02
South	0.473	0.088	0.36	0.64	2.77	0.196	2.45	3.1	1.791	0.135	1.62	2.03
Midwest	0.312	0.497	0.25	0.4	2.317	0.146	2.05	2.54	2.024	0.14	1.83	2.26

(*): Unit values

Table 4 Intermediary determinants: safe water supply and sewage service

	Water supply coverage*				Sewage service coverage*			
	Mean	SD	CI		Mean	SD	CI	
North	95.25	3.441	8.9	101	14.75	4.751	5	23
Northeast	102.67	3.055	97	109	40.67	4.64	34	47
Southeast	110	3.045	104	114	95.92	6.33	87	105
South	113.75	3.467	107	118	41.58	9.2	28	58
Midwest	117.67	3.576	112	123	28.83	7.222	19	40

(*): Percentages values

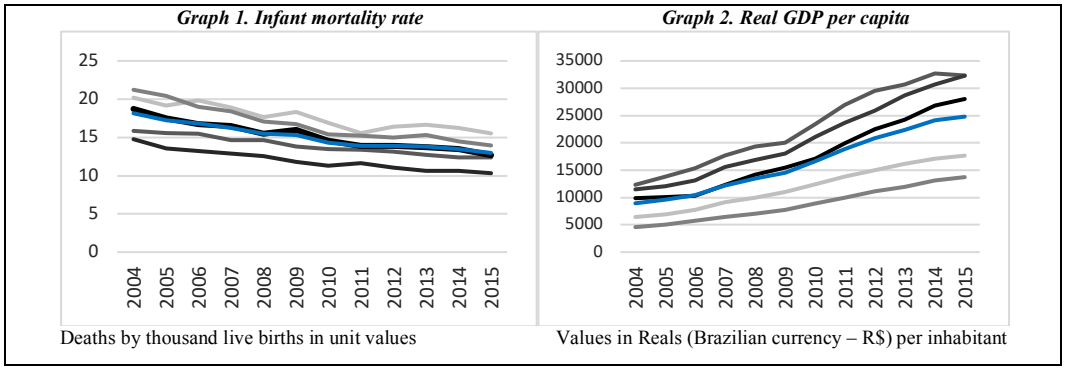
The Midwest macro-region presented the highest safe water supply average coverage rate (Table 4), and, conversely, the lowest sewage service average coverage rate, and the third lower IMR (15.26 deaths per thousand livebirths). In this regard, the South macro-region recorded the second-highest average coverage rate of water supply, and although it recorded the second-highest sewage service average coverage rate (Table 4) (41.58%), it barely reached half of the sewage service average coverage rate of the Southeast macro-region (95.92%).

In summary, the South macro-region presented the lowest average IMR, recorded the highest educational attainment and employment rates, the second-highest per capita income, BFP coverage rate, quality of prenatal care, access to health professionals, water supply coverage rate and, particularly, the second-lowest sewage service coverage rate.

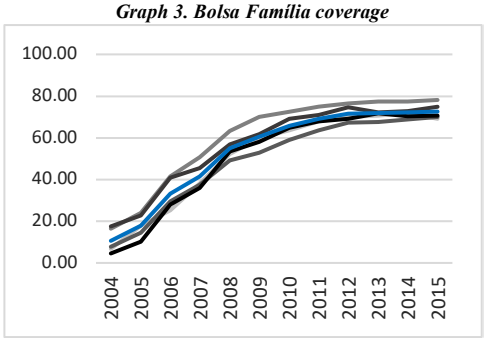
The evolution of infant mortality in Brazil and its determinants 2014-2015

Although our analysis so far suggested that there is a correlation between IMR and income, fertility rate, education, employment, BFP, and sewage services coverage rate and that there are many disparities regarding the indicators of social determinants of infant mortality in Brazil at the structural and intermediary levels, one must analyze the evolution of these factors over time to verify if these disparities are persistent and how they may impact IMR. In graphs 1 to 10 (Figure 5), we analyzed the evolution of each of these factors regarding the indicator of interest, the infant mortality rate between 2004 and 2015 according to the annual average values of indicators of the macro-regions and the country as a whole.

Figure 5 The evolution of infant mortality in Brazil and its determinants between 2004-2015 macro-regions: North ; North-east ; South-east ; South ; Middle-west and Brazil

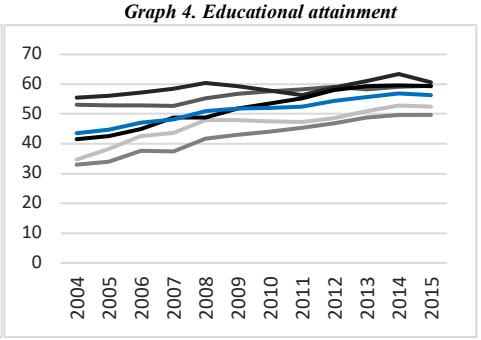


Graph 3. Bolsa Família coverage



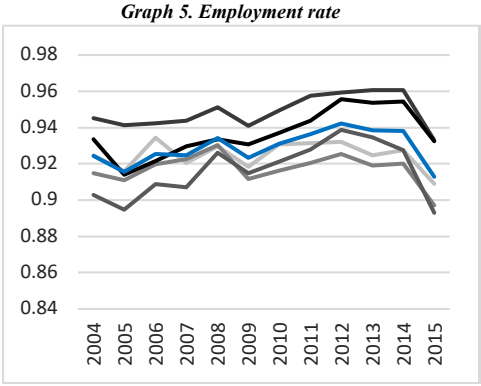
Coverage rate in percentage values

Graph 4. Educational attainment



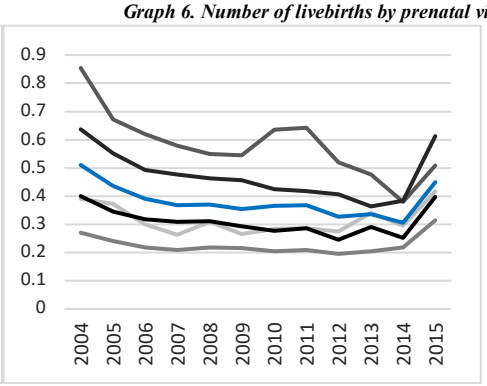
Percentage values

Graph 5. Employment rate



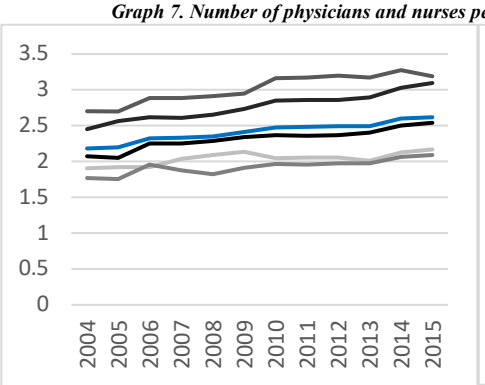
Percentage values

Graph 6. Number of livebirths by prenatal visits



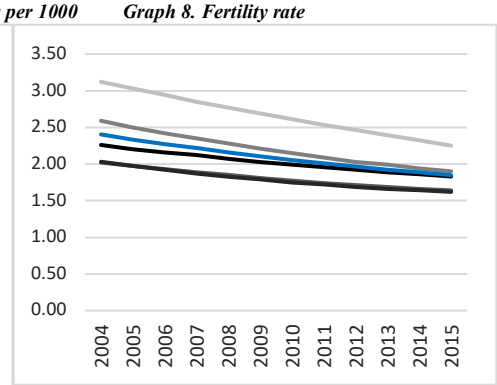
Unit values

Graph 7. Number of physicians and nurses per 1000



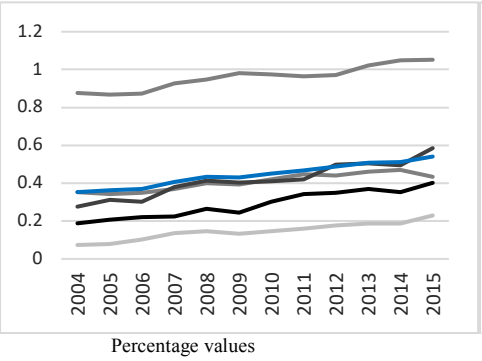
Unit values

Graph 8. Fertility rate



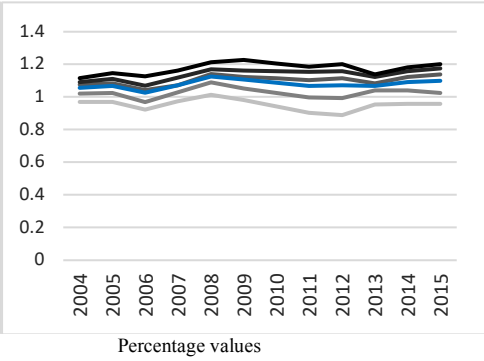
Unit values

Graph 9. Sewage service coverage rate



Percentage values

Graph 10. Water supply coverage



Percentage values

Infant mortality rate

In Graph 1 we noted a downward trend in the infant mortality rate (IMR) over the entire period, with higher rates in the North and Northeast macro-regions. We also observed that after 2005, the IMR in the North macro-region oscillated more than in other macro-regions, remaining at a higher level in relation to the others. The Northeast macro-region presented the greatest downward trend in IMR, although differences between this region and the North macro-region in relation to the others are still high, with much higher rates compared with to the national average. The IMR in the Southeast macro-region seems to decline more slowly than the country's average rates. Infant mortality rates in the South macro-region are the lowest overall period and declines seem to follow the same trend of the national average.

Per capita Income (Per capita RGDP)

Graph 2 shows that income grew over the entire period, especially after 2009. The South, Southeast, and Midwest regions presented the highest averages of per capita income, however, the Southeast macro-region presented an expressive increase of per capita income between 2014 and 2015.

Bolsa Família Program

The coverage rates of BFP (Graph 3) seem to have the greatest growth between 2004 and 2009 in all macro-regions. After this period, the BFP coverage seems to grow at decreasing rates. The Northeast and the South macro-region recorded higher coverage rates in relation to the country's average. Regarding the IMR, it should be mentioned that the Northeast macro-region presented the highest IMR at the beginning of the interval but also faster declines in relation to the others (Graph 1). As seen in the previous section, the South macro-region also presented higher coverage rates over the period and the lowest average IMR.

Educational attainment

For the educational achievement indicator, the South macro-region had the highest national average, all over the period (Graph 4). It is worth noting that such macro-region also recorded the lowest average IMR (Graph 1). The indicator of educational attainment in the Midwest macro-region, together with that of the Northeast macro-region, seems to have grown faster than the others, although, that indicator also suggests the existence of inequalities between the North and Northeast macro-regions in relation to the others.

Employment

What stands out in Graph 5 is a significant drop in the employment rate between 2014 and 2015, mainly in the Northeast and Southeast macro-regions, which reached the lowest employment levels at the end of the series. Another result to be highlighted is that the South macro-region presented the highest employment average rate throughout the period.

Intermediary determinants of infant mortality

Quality and effectiveness of prenatal care

It should be noted that during the entire period, the number of live births by prenatal visits (Graph 6) in the South and Southeast macro-regions presented the higher coefficients, with the greatest increase observed in the Southeast macro-region between 2009 and 2011. The increased performance in terms of quality of prenatal care is in line with an increase in the availability of physicians and nurses per thousand inhabitants in that macro-region (Graph 6), although the Southeast macro-region showed relative stability in the IMR during the same period (Graph 1). On the other hand, the Northeast macro-region presented the poorest performance in terms of prenatal care over the period and, conversely, the lowest availability of health professionals (Graph 7).

Availability of healthcare professionals

Although the North and Northeast macro-regions counted with a low proportion of physicians and nurses per thousand inhabitants in relation to the others (Graph 7), both macro-regions presented a slight increase of physicians and nurses between 2013 and 2015. All those macro-regions presented declines in IMR in the same period. The Southeast and South macro-region recorded a higher availability of physicians and nurses over the period, which also suggests the existence of health inequalities between macro-regions with implications to the performance of prenatal care.

Fertility rate

Graph 8 showed a steady declining trend of fertility rate over the entire period in all macro-regions. Exceptionally, the curves of the South and Southeast macro-regions in Graph 8 perfectly overlapped each other and were the ones showing the lowest fertility rates during the period. The Northeast macro-region presented the greatest decline in fertility rates between 2004 and 2015, approaching the national averages. Although the North macro-region also demonstrated important declines in fertility rate, it remained far higher in relation to the national average.

Access to safe water supply and sewage services

Regarding the access to safe water (Graph 9), there were almost imperceptible increases only in the South, Southeast, and Midwest macro-region between 2013 and 2015. Those macro-regions also presented higher levels of water supply coverage rates in relation to the national average. In the North and Northeast macro-regions, large oscillations were observed, with the coverage rates in 2015 remaining practically at the same levels as in 2004. All series seem to be stationary which may explain the huge dispersion observed in the scatterplot's diagrams and the weak probability of correlation to IMR.

On the other hand, in Graph 10, results suggest that access to sewage services probably acts differently, with different impacts depending on the socioeconomic context. The South macro-region showed an average coverage rate of sewage service that barely reached half of that observed in the Southeast macro-region, which in turn showed higher average IMR. It is noteworthy that although both macro-regions had higher average income, employment and educational achievement, lower fertility rate and greater access and quality health services, the Southeast had the highest average coverage of sewage services.

4.1.8 Discussion

This study provides a retrospective descriptive analysis of the disparities and the evolution of the determinants of infant mortality in Brazil between 2004 and 2015, based on the WHO's CSDH framework, aiming at understanding the behavior and the disparities of infant mortality rate (IMR) in recent years in Brazil.

The overall results of this study suggest a possible association between lower infant mortality rates and per capita income, education attainment, employment rate, fertility rate, quality of prenatal care, and access to health professionals. In contrast, higher infant mortality rates were observed along with all factors underlined above, in addition to lower safe water supply and sewage service coverage rates. Results also suggest that disparities in IMR observed among macro-regions in Brazil is due to huge inequalities in the distribution of those social determinants of health.

Although our data are limited to explain the slowdown in the reduction, as well as the recent increase in infant mortality indicators, results suggest that disparities in the distribution of the SDH limited further declines in the IMR, especially in the North and Northeast macro-regions. A variation in these social determinants in regard to the economic and political crisis likely has

interrupted the secular trend of declining rates. In this regard, the marked fall of the employment rate between 2014 and 2015 may have had a delayed impact on IMR, among other factors.
In this subsection we will discuss the results in light of the structural and intermediary determinants of infant mortality in Brazil.

Structural determinants of infant mortality in Brazil 2004-2015

Several results emerge from this analysis and one of the highlights is that between 2004 to 2015, the average infant mortality trend in Brazil presents a declining trend and although the Northeast macro-region presented the greatest downward trend, differences between this region and the North macro-region respecting the others persist, with fairly higher infant mortality rates in relation to the national average. Studies carried in Brazil confirmed the existence of disparities in infant mortality, with higher rates observed in the North, Northeast, and Midwest regions [10, 11], mainly linked to socioeconomic and living conditions [12] and the quality [13] and access to healthcare [14]. The literature also reported that the North and Northeast macro-regions presented the lower levels of GDP per capita [10].

An association between income and infant mortality is in line with the literature [10-12], although Garcia, in a study conducted in Brazil between 1993 and 2008, reported that income affected infant mortality but to a lesser extent over time [15], which may explain the greatest declines in IMR in the Northeast macro-region that also recorded the lowest average of per capita income, while the Southeast macro-region presented the highest average per capita income and a slower reduction in IMR. The marked reduction in IMR in the Northeast macro-region was associated with an effect of the increased coverage of FHS and BFP in reducing poverty and malnutrition, which were among the major causes of diarrheal diseases and infant mortality under-one and under-five years [16,17]. On the other hand, in a study on the effect of BFP coverage on IMR between 2003 and 2008, Shei [18] stated that IMR was already in a declining trend prior to the implementation of the BFP, although the declines appeared to have accelerated after the program was implemented.

The South macro-region demonstrated extremely higher performance in terms of educational attainment, although the results also revealed the existence of continuing inequalities in the North and Northeast macro-regions. Studies reported that IMR is inversely related to education [16, 19], stressing the greater access to healthcare by social groups with higher income, higher schooling levels and higher access to public services. Higher educational attainment also improves the

perception of health and the knowledge about different medical expertise and treatment of diseases [10].

A possible association between educational attainment and income, mediated by employment is reported in studies on the pathways of the social determinants of health and health outcome [21]. Also, in a study using data from a mixed study based on interviews conducted in the Metropolitan Area of São Paulo, Ventura *et al.* [20] reported that among adults living in the same household, the fact of one having or not having a job was indicated as a determinant of the degree of stability and vulnerability of families regarding infant mortality. In regard, one must recall that the South macro-region witnessed the lowest IMR and also recorded the highest average rates of educational attainment and employment.

Intermediary determinants of infant mortality in Brazil 2004-2015

As advocated by the WHO's CSDH, the health system is itself a social determinant of health, which also has important implications for health inequalities.

The poor performance in terms of prenatal care observed in the North, Northeast and Midwest macro-regions, also related to socioeconomic inequalities, may be related to health inequities. Evidence demonstrating that quality [13], disparities in the access of health services [22], and availability of primary care physicians [14] are factors influencing infant mortality.

These findings reinforce the idea that there is a hierarchical relationship between the structural and intermediary determinants that will allow - or not - the emergence of health inequalities related to the use of health systems [9].

The literature confirms an association between decreasing fertility rates and decreasing infant deaths [16, 17, 23]. The current study found a continuous drop in the fertility rate in all macro-regions, although inequalities were observed in the North and Northeast macro-regions. On the other hand, the South and Southeast macro-regions presented the lowest fertility rates during the period. The literature also points out an increase in primary healthcare as one of the reducers of the fertility rate in Brazil [23] which gives added strength to the idea of health systems as a SDH.

Although the literature reports an association between adequate sewage service provision and infant mortality [17], our results were controversial, as the lowest infant mortality was observed in the presence of a relatively low sewage service coverage rate. These findings suggest that by improving SDH, one may conclude that some determinants may lose relevance in relation to others. This hypothesis is in line with the saturation-threshold theory formulated by Shuval *et al.*

[25]. In a statistical study on the cost-benefit of sanitation investments in relation to the population's health, the results showed that among lower socioeconomic strata, there is a threshold below which investments exclusively in community water supply and/or sewage service result in little improvement in health status. Likewise, at the higher end of the socioeconomic scale, there is a saturation point in which further investments in conventional community sanitation could not result in significant health benefits. A higher average coverage rate of safe water in the Midwest macro-region also seems to have had a modest effect on IMR.

These findings suggest that determinants such as sanitary services, among others, may lose ability or have little or no significant impact in reducing IMR in the presence of inequalities related to other determinants. Conversely, our results pointed to educational attainment, employment and fertility rate as central drivers to both the higher and the lower infant mortality rates.

Although our data are limited to explain the decrease in reduction, as well as the recent increase in infant mortality indicators, results suggest that disparities in the distribution of the SDH limited further declines in the IMR, especially in the North and Northeast macro-regions. A variation in these social determinants in regard to the economic and political crisis likely has interrupted the secular trend of declining rates. In this regard, the marked fall of the employment rate between 2014 and 2015 may have had a delayed impact on IMR in 2016.

Strengths and limitations

This study provided a retrospective descriptive analysis of the evolution of social- and health-related determinants of infant mortality in Brazil between 2004 and 2015 using the WHO's CSDH conceptual framework. This analysis relied on a relatively long series of socioeconomic factors for assessing their evolution over time to understand the evolution of infant mortality and its determinants in recent years in Brazil. In the 2010 Census, PNAD surveys were not conducted and there were missing data for income, employment, water, and sanitation, as well as educational attainment. We used backward linear interpolation to obtain the values for 2010. For the year 2004, there were no data available in DATASUS for the number of families covered by the BFP and for the number of physicians and nurses available. We used backward linear regression for back-casting these missing data. Although there were few interpolations to estimate missing data, this fact must be taken into consideration when interpreting our results. Also, the use of secondary data is susceptible to reporting errors and estimations that also may lead to bias. The coverage rates of safe water and sewage services exceed 100%, suggesting the existence of overreporting or more

than one contract per household, which should be considered when interpreting the results. Although we suggested that there might be associations between our indicators and IMR, our data are limited to effectively allow us to prove these associations or any relation of causality.

4.1.9 Conclusion

Our study contributes to the literature by providing a comprehensive perspective of social determinants of infant mortality in light of the WHO's CSDH conceptual framework. Results suggest that inequalities in infant mortality observed among macro-regions in Brazil are related to disparities in the distribution of social determinants of health such as income, BFP coverage, education attainment, employment, fertility rate and of health-related determinants such as quality of and accessibility to healthcare and water supply, as well as sewage services. The results also suggest that these disparities limit further reductions in infant mortality, which would probably explain both the slowdown in the reduction and the tendency of the infant mortality rate to remain at relatively high levels. Although our data are limited to explain a possible cause for the increase of infant mortality rate in 2016, a possible deterioration in one or more of those determinants, such as a fall in employment rate due to the economic crisis, may be pointed out as one of the causes of interruption on the trend of decline in infant mortality.

More quantitative longitudinal studies are needed to establish an association between these determinants and infant mortality rates in Brazil, as well as to understand their dynamics.

Notes: 1. The first researcher was supported by CAPES Foundation (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, Ministry of Education of Brazil, Brasilia – DF 700040-020, Brazil – Science without Borders Program – proc. 12940/13-5), and by FESP (Faculté d'Études Supérieures – ESPUM – École de Santé Publique de l'Université de Montréal); 2. We hereby declare that there is no conflict of interest related to this study and funding agencies.

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Article 3. Health Capabilities and the Determinants of Infant Mortality in Brazil, 2004-2015: an innovative methodological framework

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4.1.11 Abstract

In article 3 we conducted a series of multilevel panel data with fixed effect nested within-cluster based on the CMHC to identify the factors affecting the infant mortality indicators aiming at raising plausible hypothesis to explain the behavior and the disparities of infant mortality observed in recent years in Brazil, after the implementation of FHS and BFP. The estimations were able to isolate the effects of the variables under study from factors not observed, which are subject to estimation errors due to different degrees of error homogeneity within and between clusters. Our models allowed us to infer more about specific factors related to infant mortality rates such as the relation between the employment rate and infant mortality and between the BFP and neonatal mortality, or the threshold of household income that acts as a protective factor for infant mortality. Furthermore, the use of this methodology is a low cost-benefit solution, considering that it relies on a low volume of data when compared to conventional panel data studies.

Keywords: Multilevel panel data with fixed effect nested within-cluster, infant mortality, health capabilities, public policies, social determinants of health

Health Capabilities and the Determinants of Infant Mortality in Brazil, 2004-2015: an innovative methodological framework

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Background: Despite the implementation of a set of social and health policies, Brazil has experienced a slowdown in the decline of infant mortality, regional disparities and persistent high death levels, raising questions about the determinants of infant mortality after the implementation of these policies. The objective of this article is to propose a methodological approach aiming at identifying the determinants of infant mortality in Brazil after the implementation of those policies.
Method: A series of multilevel panel data with fixed effect nested within-clusters were conducted supported by the concept of health capabilities based on data from 26 Brazilian states between 2004 and 2015. The dependent variables were the neonatal, the infant and the under-five mortality rates. The independent variables were the employment rate, per capita income, Bolsa Família Program coverage, the fertility rate, educational attainment, the number of live births by prenatal visits, the number of health professionals per thousand inhabitants, and the access to water supply and sewage services. We also used different time lags of employment rate to identify the impact of employment on the infant mortality rates over time, and household income stratified by minimum wages to analyze their effects on these rates.
Results: The results showed that in addition to variables associated with infant mortality in previous studies, such as *Bolsa Família* Program, per capita income and fertility rate, other factors affect child mortality. Educational attainment, quality of prenatal care and access to health professionals are also elements impacting infant deaths. The results also identified an association between employment rate and different infant mortality rates, with employment impacting neonatal mortality up to three years and that a family income below 2 minimum wages increases the odds of infant deaths.
Conclusion: The results proved that the methodology proposed allowed the use of variables based on aggregated data that could hardly be used by other methodologies.
Keywords: Infant mortality, health capabilities, public policies, social determinants of health, multilevel panel data with fixed effect nested within-clusters, health economics

4.1.12 Background

Context

Despite the implementation of a set of social and health policies aiming at improving the health of its populations [1], Brazil has experienced since 2009 a slower decline in infant mortality rates [2], recording major regional disparities and persistent high death levels [3, 4]. Such facts raise questions about the determinants of infant mortality after the implementation of those policies and their role as levers to grant a sustainable decline in infant mortality in Brazil.

The SUS - *Sistema Único de Saúde* (Brazilian Unified Health System) was created in 1988, with the implementation of the primary health program, the Family Health Strategy (FHS), in 1994. The FHS provided services delivered by multidisciplinary teams, comprising a physician, a nurse, a nurse assistant and community health professionals. A geographical area was assigned to each team which was responsible for the health of the population living in that area. All services were provided free of charge. In January 2017, the FHS counted on 39709 teams, covering 97% (n=5398) of the municipalities in Brazil [5].

In 2003, the Ministry of Social Development implemented the *Bolsa Família* Program (BFP) that provided monthly cash transfers to poor families in exchange for their complying with health and educational conditionalities. Those conditionalities required parents to ensure that children younger than seven years of age to comply with a routine of growth monitoring and the childhood vaccination schedule and pregnant women and nursing mothers to attend prenatal care and nutrition education programs in a local healthcare provider. The educational conditionalities stipulated that children aged 6–17 were enrolled in school and maintained a minimum attendance rate according to their age bracket [6]**.** Since the implementation of the SUS and the FHS and BFP Programs, maternal and infant mortality declined [7], the fertility rate in poorer areas also decreased [8], life expectancy increased and a sharp decline in mortality due to transmissible diseases was recorded [9].

However, despite all those advancements, since 2009, the declining trend in infant mortality seems to have lost its momentum [2-4]. Between 2011 and 2016, Brazil experienced an economic and political crisis and in 2016 the declining trend of infant mortality was interrupted and increases in under-one and under-five-year-old mortality were observed in many regions of the country [2, 10, 11]. Those facts draw attention to possible effects of social determinants of health (SDH) that are

beyond the reach of social and health policies and which may have influenced this change in the trend of infant mortality rates.

Maternal and child health are very closely related to social determinants of health that go beyond the impacts of adequate health services provision. Thus, infant mortality is also influenced by socioeconomic and living conditions factors such as income, employment and housing [12]. The infant mortality rate (IMR) is known as an indicator of population health, of health systems performance, and a useful tool for comparing social and health inequalities among populations [12-15].

In this sense, in addition to income and wealth growth that may improve living standards, Nussbaum places as fundamental capabilities being able to have bodily health, including reproductive health and making reproductive choices and to participate effectively in political choices [16]. According to the capabilities approach, inequalities in health result from gaps between the subjective freedom and substantive freedom of individuals. The notion of traditional economic development based on income and wealth does not capture the different dimensions of human development, which is, in fact, the means and the end of socioeconomic development. This point of view takes into consideration the real freedom of individuals as dependent on the expansion of their functional capacities, through access to essential resources such as the freedom of access to education, being in good health conditions, having access to healthcare, income and jobs, among other capabilities [16-19]. The concept of health capabilities is derived from the capabilities approach that was initially proposed by Nobel Prize in Economics Amartya Sen, but has been supported by numerous researchers that are dedicated to advancing knowledge about social justice and human development [16-22].

Many quantitative studies have been successful in establishing an association between the coverage rate of those health and social programs implemented in Brazil and different infant mortality indicators [6, 23-28]. However, those studies were dedicated exclusively to analyzing the combined effects of those programs between 1998 and 2010, when the country experienced a period of certain stability and economic growth, with rising employment and per capita income rates [29-31]. In addition, those studies relied on socioeconomic variables, such as per capita income, maternal schooling, and access to the safe water supply as control variables. Some of them were based on longitudinal and panel data analysis, with interpolated data for long periods, excluding a considerable number of municipalities in rural areas of the North macro-region of the

country due to the unavailability of socioeconomic data until 2003 [28, 32], or limiting the analysis to a fraction of the totality of the municipalities of the country [25]. Also, none of those studies has attempted to use the capabilities approach to assess a possible association between SDH, such as employment or educational attainment, and infant mortality rates.

An important challenge to be addressed when using data in Brazil is the operationalization of variables based on data observed in different administrative instances over time. In Brazil, some data, especially employment and unemployment rates, are regularly estimated and disseminated only at the level of large metropolitan areas, states, and the country as a whole. Also, to use those data, one must consider the socioeconomic disparities among the macro-regions of the country. An additional challenge when using aggregated data is the risk of falling into the ecological fallacy and producing incorrect and biased estimations.

The objective of this article was to perform multilevel panel data with fixed effect nested within-cluster, based on the Conceptual Model of Health Capabilities CMHC as a methodological approach aiming at identifying the determinants of infant mortality in Brazil, after the implementation of FHS and BFP.

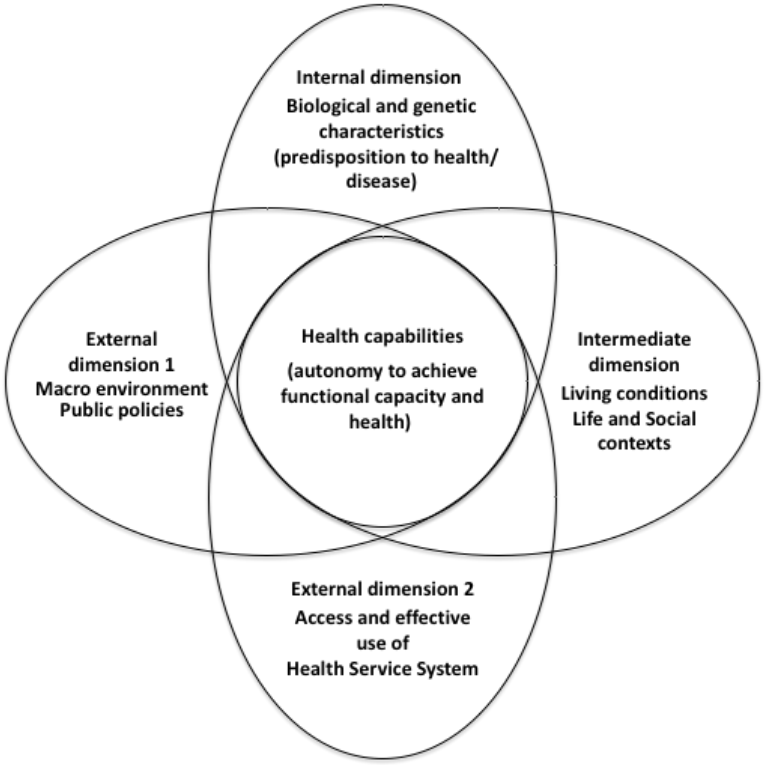
The Conceptual Model of Health Capability (CMHC)

Under the perspective of Nussbaum, the concept of capabilities is closely related to rights that may be interpreted in a double sense. First, thinly and negatively, rights are preserved as long as the government does not interfere, or in a positive way such as by adopting the capabilities approach for which they require affirmative government support for creation and preservation [16]. According to the latter, the new Constitution enacted in Brazil in 1988 granted the right to health as a fundamental human right and an obligation of the State, launching the basis for the implementation of the SUS, conceived as a universal and equitable public health system aiming to provide health and social security to the entire population, and social and health policies such as BFP and FHS. The BFP was designed to interact with the FHS to increase both supply and demand for health services by motivating poor families to seek health and education through monetary incentives in exchange for complying with the program's conditionalities [28].

In this regard, the CMHC (Figure 1) has as its central idea that individuals seek both health and the ability to seek health [21]. Based on the concept of capabilities developed by Sen [17-19], the CMHC takes into account the individual's sense of health and functional capacity for achieving

health capability as the result of the interaction of three social dimensions, given one's specific individual characteristics, the internal dimension.

Figure 1 Conceptual Model of Health Capability (CMHC) adapted (Ruger 2010)



The main assumption of the CMHC is that the individual's health capabilities result from the interaction of four dimensions, one dimension referring to macro, social, political, and economic environment, the second related to the effective use of the health system, an intermediate dimension referring to the social and life contexts, given an internal dimension corresponding to the individual's biologic and genetic predisposition to health/disease. In essence, the individual's health capability is the ability to achieve health goals that an individual values, acting as his or her own health agent (health agency) and the health outcome itself as actions to keep and/or improve health (health functioning), both resulting from the interactions (arrangements) between the four dimensions of the CMHC. In this framework, there is a fine dividing line between state paternalism and self-agency as drivers to an individual for pursuing and keeping health as social and economic values.

The concept of health capabilities is increasingly becoming a valuable tool for the analysis of SDH. Furthermore, in this perspective, infant mortality has been identified as an adequate indicator of health attainment (health functioning), while the SDH such as education, housing, employment,

and economic inequalities have been identified as social and environmental conversion factors (capabilities) [22].

Considering that the CMHC was developed as a tool for designing health policies and interventions in developed countries, some considerations must be made with respect to the specific characteristics of an emerging country when using this framework. Brazil is the largest Latin American country and the world's fifth-largest, with a population of approximately 212 million people. Despite being considered an upper-middle-income country by the World Bank, the country ranks 73rd in terms of per capita income. Some social and structural aspects must be considered, such as high socioeconomic inequalities and low sewage services coverage rates (approximately only 60% of households on average are connected to the sewage collection and treatment network), for instance.

More as a disclaimer than an adaptation proposal, some aspects of our proposal to use the CMHC as an analysis tool should be highlighted. In the original model of the CMHC, external dimension 2 encompasses the influence of Public Health and health system and implicitly some aspects inherent to developed health systems, as financial equity and security. In this sense and considering the specificities of Brazil and that the basis of the capabilities concept is how people effectively live their lives, their freedom of choice (capabilities) and well-being (functionings), we consider income and socioeconomic inequalities, housing and overall living conditions as part of life circumstances in the intermediate dimension.

Infant mortality, the Brazilian macro-regions, and data structure

Under the perspective of the health capabilities approach, to be able to have bodily health, reproductive health, making reproductive choices, and to control one's social and physical environment, including to hold property and seek employment lie among the individual's fundamental capabilities [16, 19, 20]. In this sense, infant mortality rates, our variables of interest, may be considered as indicators of population health attainment (health functioning) and education, employment, housing, access to health and economic inequalities as social and environmental conversion factors (capabilities).

The 26 Brazilian states and the Federal District (FD) are grouped into five major macro-regions with very distinct socioeconomic, political, institutional, and cultural characteristics: North (1), Northeast (2), Southeast (3), South (4), and Midwest (5) (Figure 2). Those socioeconomic characteristics are homogeneously distributed within macro-regions.

Figure 2 Brazilian macro-regions - (IBGE, https://ibge.gov.br)

From the perspective of social determinants of health, identifying the factors affecting a health outcome requires the operationalization of variables that must fit for modeling multidimensional relations [33, 34]. To organize the possible factors acting on infant mortality among those different administrative instances over time, aiming to find statistically meaningful evidence when errors are differently distributed within and between macro-regions is a great challenge [33-35].

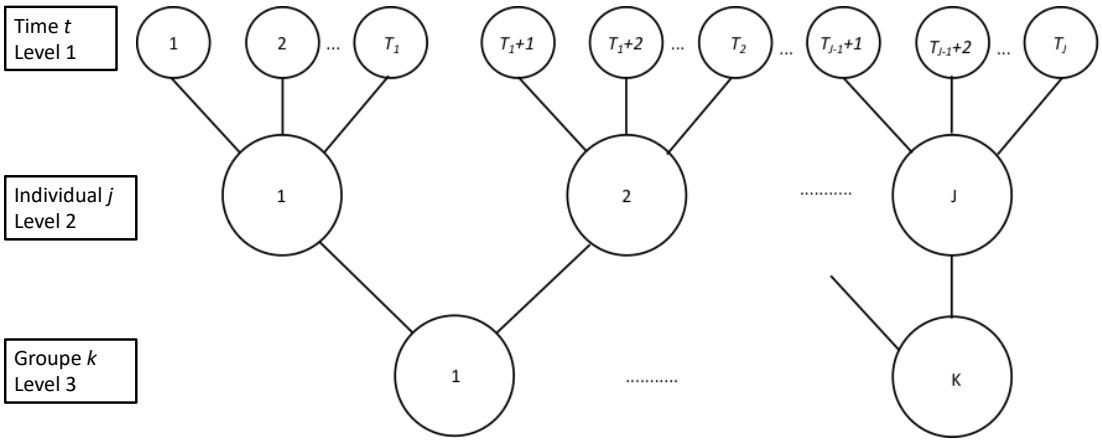
4.1.13 Methods

Panel and data specifications

Multilevel panel data

According to Moulton, [36]**,** modeling data from grouped structures based upon the assumption of independent disturbances is not appropriate. Individuals' (units) observations over time within the aggregate level, as states nested in macro-regions, are clustered and are more similar to each other than units from another cluster. In this type of data structure there are clustered errors and they occur because unobserved factors varying over time are more homogeneous among clustered units than others and there are different levels of fixed effects within and between clusters [37]. The statistical study with such data structure (Figure 3) demands multilevel clustering panel data [38].

Figure 3 Three-level clustered structure with repeated measures



Reference: Hair & Favero, 2019 [36].

In this data structure, the errors are not i.i.d. and the within-cluster errors (υ_{tjk}) may occur and are broken down in a common choke component in a given observation (ν_k, cluster-specific error) and an idiosyncratic component (ζ_{jk}), as follows:

$$\upsilon_k = \nu_k + \zeta_{jk}$$

VCE (variance-covariance matrix of estimators)

The absence of clustering control may lead to underestimated standard errors and overestimated statistical significance. In this sense, by relaxing the assumption of i.i.d. errors, opting for a more realistic data structure that allows intragroup correlations, we should consider the use of a cluster-robust variance-covariance matrix of estimators (VCE) [39, 40].

Data structure, variables, and data sources

We created a secondary aggregated database from 12 periods (years) between 2004 and 2015 and having as units of analysis the 26 Brazilian states, distributed among the 5 socioeconomic macro-regions (Figure 2). The country's capital, Brasília, is a hybrid administrative instance (city-state) which presents a disproportionate per capita income when compared to other states, which may introduce bias in our models. Therefore, Brasília was excluded from our study. The study period was defined considering the beginning of BFP that was officially implemented in October 2003, as well as the availability of data regarding the employment rate. We used the data series collected and disseminated by the PNAD (National Household Sample Survey). In 2012, the PNAD evolved to PNAD Continuous, on a monthly basis, and in 2015, the Brazilian Institute of Geography and Statistics (IBGE) stopped publishing the former PNAD annual series referring to employment

rates. By coding the states (id: from 1 to 26) and macro-regions (mr: from 1 to 5), we attributed categorial variables in the model to nest states (id) within-clusters (mr and years). We relied on 312 observations from 26 Brazilian states over 12 years, nested in 60 clusters (5 macro-regions times 12 years). Our dataset is balanced, implying that observations are corresponding to all units over our study period (T2 – T1 = … TJ – TJ-1).

Dependent variables

Our dependent variables were the neonatal mortality rate (NMR), infant mortality rate between 0 and 1 year (IMR), and infant mortality rate between 0 and 5 years (U5MR). Those indicators are widely used in infant mortality studies. This will allow us to compare our results with those of other studies. The dependent variables were indicators of the population's health attainment (health functioning).

Independent variables

According to a scoping review based on the CMHC, we identified possible determinants of infant mortality acting simultaneously with the social and health policies implemented in the country since 2004. The capabilities approach suggests that the employment/unemployment rate is one of the conversion factors (capabilities) of health functioning (infant mortality) among the factors accounting for the infant mortality rate. We decided to use the employment rate (occupancy rate) rather than the unemployment rate due to methodological changes in the estimation and publicity of the unemployment rate in Brazil in recent decades. For surveys carried out between 1983 and 2002, IBGE considered the population at working-age (PWA) to be those over fifteen years of age. According to the IBGE's new methodology, over 10 years old were part of the working-age population. In defining the employed or unemployed population, IBGE considered the minimum limit of 15 hours per week for unpaid work, while the new survey included those who worked at least one hour a week[1]. Also, the capabilities approach is a positively conceived concept in the sense that one of the basic capabilities is a person's freedom to be able to seek employment. In addition to using the annual employment rate (OCC), we used three different time lags. The variables OCC, OCC1, OCC2 and OCC3 referred to the employment rate by considering zero-, one-, two- and three-years-time lags respectively, in relation to both the dependent and other

[1] Information available at the National Employment Survey (IBGE-*Pesquisa Mensal de Emprego*): ftp://ftp.ibge.gov.br/Trabalho_e_Rendimento/Pesquisa_Mensal_de_Emprego/Metodologia_da_Pesquisa/srmpme_2ed.pdf.

independent variables. This strategy aimed at determining to which extent the employment rate may impact infant mortality. In an econometric study on the economic fluctuations in the USA as well as infant and maternal mortality, Brenner [41] demonstrated that in industrialized countries, the association between the unemployment rate and infant mortality can vary between 0 and 5 years and that the optimal time lag lies between 1 and 2 years, depending on the infant mortality. Per capita income (represented by the Real Gross Domestic Product per capita) is also considered an important conversion factor related to both the macro-environment (as the result of macroeconomic management and policy) and the intermediate dimension (socioeconomic inequalities and living conditions). We also stratified income by number the average nominal minimum wages earned by households as an attempt to identify income inequalities that may be affecting infant mortality indicators. This variable was stratified according to the following categories: low-income: from 0 to 1 minimum wage (IS_F <1 MW); low-medium income: 1 to 2 minimum wages (1 MW <IS_E <2 MW); medium-income: from 2 to 5 minimum wages (2 MW <IS_D <5 MW); medium-high income: from 5 to 10 minimum wages (5 MW <IS_C <10 MW); high-income: 10 to 20 minimum wages (10 MW <IS_B <20 MW) and very high income: more than 20 minimum wages (IS_A> 20 SM). The coverage rate of the PBF was used to assess the effect of a macro-environment-related social policy on the different infant mortality indicators. The fertility rate was a control variable. The variables concerning safe water supply and sewage services were used to evaluate housing and living conditions as factors of the intermediate dimension impacting infant mortality rates. The number of live births by prenatal visits was a proxy of the effectiveness and quality of prenatal care. We also conducted estimations using the number of physicians and nurses by thousand inhabitants, which was designed in order to assess the impact of the availability of health professionals on infant mortality. This variable may also be interpreted as a proxy to evaluate the access and comprehensiveness of healthcare, regardless of the availability of health facilities. The educational attainment ratio is an important variable in our conceptual framework. Like the dependent variables that measures infant mortality as a health functioning variable, educational attainment measures educational functioning. Both infant mortality and educational attainment are capabilities “converted” into functionings. Although in the original CMHC there are no references of educational attainment, it is reasonable to suppose that there is a connection between the development of health and educational capabilities at the household level as a result of the interaction of the four social dimensions of the CMHC.

For the variables already expressed in unit values, such as the number of live births by prenatal visits, the number of nurses per thousand inhabitants, the fertility rate, as well as dependent variables NMR, IMR and U5MR, no transformations were applied. For all variables expressed in percentages, such as employment rate (OCC), the proportion of family income expressed in minimum wages (IS_A to IS_F), the coverage rate of the BFP, sewage services and water supply coverage rates, we divided the percentage values by 100 to convert them also into unit values. Regarding household per capita income (RGDP), this figure was divided by one thousand. As those are linear transformations, they do not affect estimations, but allow a better analysis of the results in terms of magnitude.

For the Census Year of 2010, PNAD surveys were not conducted and there were no values for some variables in that specific year since the IBGE uses different samples and methodology for Census and PNAD. Thus, for employment (OCC), per capita income (RGDP), household income stratified by the number of average nominal minimum wages (IS_A to IS_F), water and sanitation data, total safe water coverage (WCT), sewage collection and treatment coverage (SWT), and educational attainment (EDA) we applied linear interpolation to obtain the values for 2010.

The dependent and independent variables and their definitions are displayed in Table 1. according to the dimensions of the CMHC.

Table 1 Variables according to the CMHC

Variable name	Abbreviation	Description/ expected signal	Data source	Dimension according to the CMHC
Neonatal mortality rate	NMR	The ratio of the children who died during the first 28 days of life and those born alive in a given year	Ministry of Health/DATASUS	Dependent
Infant mortality rate	IMR	The ratio of children who died under-one-year of age to those born alive in a given year	Ministry of Health/DATASUS	Dependent
Under-five mortality rate	U5MR	The ratio of children who died under-five-years of age to those born alive in a given year	Ministry of Health/DATASUS	Dependent
Employment rate	OCC	The ratio between the total of employed population aged 10 years or more (occupation rate) and the total of the economically active population	IBGE/PNAD Survey	External 1
Income per capita (Real GDP)	RGDP	Deflated Gross Domestic Product (RGDP) of a state divided by its number of inhabitants in a given year	IBGE/PNAD Survey	External 1
Household income according to minimum wage strata	IS_A to IS_F	The ratio between the income measured in terms of the minimum wage earned by households and the total households in the state	IBGE/PNAD Survey	Intermediate
***Bolsa Família* Program**	BFP	The proportion between the families followed up by the BFP and the number of families to follow in a given year	Ministry of Health/DATASUS	External 1
Fertility rate	FR	The ratio between live births in a given year and the total female population	Ministry of Health/DATASUS	Intermediate

		at reproductive age (between 15 and 49 years)		
Safe water supply	WCT	The proportion of total households with access to safe water supply service in relation to the total households in the state in a given year	IBGE/PNAD Survey	Intermediate
Sewage services	SWT	The proportion of total households with access to sewage services in relation to the total households in the state in a given year	IBGE/PNAD Survey	Intermediate
Quality of prenatal care	LBPRE	The proportion of live births by the state in a given year by the number of prenatal visits of women at reproductive age in the state in a given year	Ministry of Health/DATASUS	External 2
Access to health professionals	MEDEN	The sum of the average number of physicians plus the average number of nurses in a given year divided by thousand inhabitants living in a state	Ministry of Health/DATASUS	External 2

Data sources

All infant mortality rates were obtained by computing data directly from infant deaths recorded in the SIM and births recorded in SINASC systems provided by DATASUS database (TABNET) without any further adjustment. Even though certain references highlight the limitations for the direct calculation of infant mortality rates such as underreporting [42, 43], we adopted this approach supported by the fact that an important question regarding indirect method to calculate infant mortality rate is that corrections are made building on data from relatively small samples and/or census surveys which tends to smooth the trend of infant mortality over time and attenuate short term variations, which is a very undesirable factor to longitudinal analysis. Estimates derived from forecasts relied on the adjustments applied to observed historical data do not take into account the effect of short-term changes resulting from health and social programs and may hide their influence on infant mortality. Further, they may also hide the real impact of economic and political crisis on infant mortality rates. Many longitudinal and ecological studies have been done also based directly on data from the Ministry of Health's mortality information systems (SIM) and live births (SINASC) [1, 6, 26, 44-47].

The employment rate (OCC), the fertility rate (FR), the school attainment rate (EDA), Real Gross Domestic Product per capita (RGDP), and the household income stratified by socioeconomic categories (IS) were obtained from the database of IBGE[2]. Those data were estimated through the PNAD survey. The PNAD was conducted annually by the IBGE since 1981 and surveyed several characteristics of the population such as household structure, education, labor, income, and fertility. The PNAD sample in 2012 consisted of 147,203 households, with 362,451 residents.

[2] Information available at http://www.ibge.gov.br.

For the Census Year of 2010, PNAD surveys were not conducted and there were no values for some variables in that specific year since the IBGE uses different samples and methodology for Census and PNAD. Thus, for employment (OCC), per capita income (RGDP), household income stratified by the number of average nominal minimum wages (IS_A to IS_F), water and sanitation data, total safe water coverage (WCT), sewage collection and treatment coverage (SWT), and educational attainment (EDA) we applied linear interpolation to obtain the values for 2010).

Data on dependent variables (NMR, IMR and U5MR), as well as data on the families followed by the BFP and the number of live births in relation to the number of prenatal visits, and the proportion of physicians and nurses per thousand inhabitants, were obtained from the database of the Brazilian Ministry of Health, DATASUS[3].

For the year 2004, there were no data available in the DATASUS for the number of families covered by the BFP and for the number of physicians and nurses (MEDEN). We used backward linear regression forecasting ("backcasting" in fact) to generate values for the number of physicians and nurses for that year. For BFP coverage specifically, as the program was implemented in October 2003, we applied data only from the period when the program had expanded from 2005 to 2009 to estimate values for 2004.

Statistic model

The general panel data model for our three-level dataset structure is noted in Figure 4 as follows:

Figure 4 Panel data with three level structure notation

Level 1 Period "*t*" *(repeated measure)*	Level 2 (Observation) (STATES "j")	Level 3 (Macro-regions "K")	Y_{tjk}	$X1_{jk}$	X_{2jk}	…	X_{Qjk}	W_{2K}	W_{2k}	⋮	W_{Sk}
1	1	1	Y_{111}	X_{111}	X_{211}	…	X_{Q11}	W_{11}	W_{21}	⋮	W_{S1}
2	1	1	Y_{211}	X_{111}	X_{211}		X_{Q11}	W_{11}	W_{21}		W_{S1}
⋮	⋮	⋮	⋮	⋮	⋮		⋮	⋮	⋮		⋮
T_1	1	1	$Y_{T_1 11}$	X_{111}	X_{211}		X_{Q11}				
T_1+1	2	2	$Y_{T_1 1,21}$	X_{121}	X_{221}		X_{Q21}				
T_1+2	2	2	$Y_{T_2 2,21}$	X_{121}	X_{221}		X_{Q21}				
⋮	⋮	⋮	⋮	⋮	⋮		⋮	⋮	⋮		⋮
T_2	2	2	$Y_{T_2 21}$	X_{121}	X_{221}		X_{Q21}	W_{11}	W_{21}		W_{S1}
⋮	⋮	⋮	⋮	⋮	⋮		⋮	⋮	⋮		⋮
$T_{J-1}+1$	J	K	$Y_{T_{J-1}+1JK}$	X_{1JK}	X_{2JK}		X_{QJK}	W_{1K}	W_{2K}		W_{SK}
$T_{J-1}+2$	J	K	$Y_{T_{J-1}+2JK}$	X_{1JK}	X_{2JK}		X_{QJK}	W_{1K}	W_{2K}		W_{SK}
⋮	⋮	⋮	⋮	⋮	⋮		⋮	⋮	⋮		⋮
T_J	J	K	$Y_{T_J JK}$	X_{1JK}	X_{2JK}		X_{QJK}	W_{1K}	W_{2K}		W_{SK}

Adapted from: Hair & Favero, 2019 [36].

[3] Information available at http://www2.datasus.gov.br/DATASUS/index.php?area=02.

The general statistical model specification observes the following formulation:
$Y_{ijt} = \alpha_{ijt} + \beta_1 OCC_{ijt} + \beta_2 RGDP_{ijt} + \beta_3 BFP_{ijt} + \beta_4 FR_{ijt} + \beta_5 EDA_{ijt} + \beta_6 LBPRE_{ijt} + \beta_7 WCT_{ijt} + \beta_8 SWT_{ijt} \ldots + \upsilon_{ij} + \varepsilon_{ijt}$, where:

"Yijt" is the result of the unit (scalar) at time "t", "αijt" is the intercept specific to each unit and: "OCCijt"; "RGDPijt" (or alternatively: " IS_Aijt "," IS_Bijt "," IS_C ijt "," IS_Dijt "," IS_Eijt "," IS_Fijt"); "BFPCOVijt"; "FRijt", "EDAijt"; "LBPREijt"; "WCTijt" and SWTijt" are the vectors (1 x K) of the covariant which vary over time. The β's are the vectors of the coefficients and "υ_{ij} "= ν_k + ζ_{jk}, is the decomposed scalar of the clustered fixed effects and "ε_{ijt}" is the error term.

This model considers the parameters and specifications established by the "reghdfe" command of statistical software Stata©, version 13, for multilevel panel data.

Statistical analysis

First, we calculated a correlation matrix (Appendix 3) with all variables to evaluate the correlation between the independent and dependent variables and the signals of those correlations to compare those results with the estimations.

As discussed previously, our dataset structure is based on different levels of fixed effects. We opted for estimating multilevel linear regressions panel data using Correia's [48] multilevel panel data with fixed effect nested within the cluster model. By using Correia's multilevel panel data with fixed effect nested within the cluster model we can treat observations at different levels of homogeneity. Further, by absorbing categorical variables, as time (years), and clustering combined fixed effects levels as time and macro-regions (mr), as "years" and "mr", we did not double penalize the robust standard errors when computing the absorbed degrees of freedom. Appendix 4 shows the general model for infant mortality rate (IMR) and employment rate with one-year-time lag (OCC1), absorbing year.

Study design

We conducted 4 sets of estimations with 33 data panels with fixed effect nested within-cluster models alternating between the three dependent variables (NMR, IMR, and U5MR) and their possible association with the independent variables. In the first set, 12 panels combined the three alternatives of time lags for employment rate (OCC, OCC1, OCC2, and OCC3) to identify if the three dependent variables (NMR, IMR, and U5MR) were associated with employment rate, and, if so, what was the optimal time lag according to the specific infant mortality indicator. After identifying the best adjusted time lag for a possible association between employment and all infant

mortality rates we estimated a general model using all other covariates: per capita income (RGDP), BFP coverage (BFP), the fertility rate (FR), educational attainment (EDA), total live births by the number of prenatal visits (LBPRE), water supply coverage (WST) and sewage services coverage (SWT). For the income stratified (from ISA to ISE), in the third set, we ran 18 panels combining the three dependent variables (NMR, IMR, and U5MR). Finally, we conducted 3-panel models in the fourth set to compare the effect of the availability of physicians and nurses (MEDEN) and the variable live births by the number of prenatal visits (LBPRE) in the general model to assess the effective use and access to the health system in association with the dependent variable (NMR, IMR and U5MR).

4.1.14 Results

After estimating the 33 models, we present the main results and comments in the tables below. Table 2 summarizes the results of the first set of estimations using the different time lags for employment rate (OCC, OCC1, OCC2, and OCC3) and our dependent variables: neonatal mortality rate, infant mortality rate, and under-5 mortality rates. We controlled all models for other covariates: Real GDP per capita, BFP coverage, fertility rate, educational attainment, number of live births by prenatal visits and safe water supply and sewage services coverage rates.

Table 2 Estimations using the different time lags for employment rate (OCC)

	NEONATAL MORTALITY				INFANT MORTALITY				UNDER-FIVE MORTALITY			
	Coef.	(95% CI)	R^2	p-value	Coef.	(95% CI)	R^2	p-value	Coef.	(95% CI)	R^2	p-value
EMPLOYMENT WITHOUT TIME LAG	-17.50	(-29.53, -5.47)	0.60	0.005	-17.27	(-29.97, -4.56)	0.74	0.009	-10.94	(-30.93, 9.05)	0.71	0.278
EMPLOYMENT WITH 1-YEAR TIME LAG	-17.73	(-28.98, -6.49)	0.60	0.003	-19.18	(-30.94, -7.43)	0.74	0.002	-17.63	(-31.32, -3.95)	0.71	0.012
EMPLOYMENT WITH 2-YEARS TIME LAG	-19.95	(-32.23, -7.68)	0.61	0.002	-12.83	(-23.66, -2.00)	0.73	0.021	-16.11	(-27.99, -4.24)	0.71	0.009
EMPLOYMENT WITH 3-YEARS TIME LAG	-20.57	(-32.05, -9.08)	0.61	0.001	-11.48	(-21.99, -0.96)	0.73	0.033	-9.87	(-22.76, 3.02)	0.71	0.131

R^2 REFERS TO ADJUSTED VALUES

The estimations with different infant mortality rates show that the employment rate is best adjusted to IMR with a one-year time lag (p-value: 0.002, CI: -30.94; -7.43 and adj. R^2: 0.74) and with a two-year time lag for under-five mortality (p-value: 0.009, CI: -27.99; -4.24 and adj. R^2: 0.71). Curiously, for the association between the employment rate and NMR, the estimations show that there is a gradient from the less statistically significant association, with no time lag (p-value: 0.005, CI: -29.53; -5.47 and adj. R^2: 0.60) to the most statistically significant, with three-year-time lag (p-value: 0.001, CI: -32.05; -9.08 and adj. R^2: 0.61).

Table 3 presents the estimations for the general model with all other covariates and their association with infant mortality rates. The estimations were made using a general panel data model with a one-year time lag for employment rate since it was the time range that most fitted the models, the Real GDP per household, the BFP coverage, fertility rate, educational attainment ratio, number of live births by prenatal visits and safe water supply and sewage services coverage rate.

Table 3 General model with one-year employment rate time lag

	NEONATAL MORTALITY				INFANT MORTALITY				UNDER-FIVE MORTALITY			
	Coef.	(95% CI)	R^2	p-value	Coef.	(95% CI)	R^2	p-value	Coef.	(95% CI)	R^2	p-value
EMPLOYMENT WITH ONE-YEAR TIME LAG	-17.73	(-28.98, -6.49)	0.60	0.003	-19.18	(-30.94, -7.43)	0.74	0.002	-17.63	(-31.32, -3.95)	0.71	0.012
PER CAPITA INCOME (RGDP)	-0.11	(-0.15, -0.07)	0.60	0.000	-0.07	(-0.12, -0.01)	0.74	0.017	-0.08	(-0.15, -0.17)	0.71	0.015
BOLSA FAMÍLIA COVERAGE RATE	-5.88	(-9.18, -2.59)	0.60	0.001	-4.83	(-7.43, -2.23)	0.74	0.000	-3.65	(-6.72, -0.60)	0.71	0.020
FERTILITY RATE	0.67	(-0.02, 1.38)	0.60	0.056	3.19	(2.25, 4.12)	0.74	0.000	4.00	(3.00, 5.00)	0.71	0.000
EDUCATIONAL ATTAINMENT	-3.85	(-6.20, -1.50)	0.60	0.002	-7.13	(-10.20, -4.07)	0.74	0.000	-8.23	(-11.59, -4.87)	0.71	0.000
LIVE-BIRTHS BY PRENATAL VISITS	-1.34	(-2.58, -0.11)	0.60	0.034	-1.33	(-2.81, 0.15)	0.74	0.076	-0.93	(-2.48, 0.62)	0.71	0.233
SAFE WATER SUPPLY COVERAGE RATE	0.76	(-0.08, 1.61)	0.60	0.077	0.54	(-0.45, 1.53)	0.74	0.279	-0.59	(-1.79, 0.60)	0.71	0.326
SEWAGE SERVIVE COVERAGE RATE	-0.32	(-0.91, 0.28)	0.60	0.291	0.32	(-0.44, 1.07)	0.74	0.407	-0.65	(-1.55, 0.25)	0.71	0.154

R^2 REFERS TO ADJUSTED VALUES

As already mentioned, there is an important effect of employment on almost all infant mortality indicators, especially on IMR. Per capita income also has a statistically significant association with all infant mortality indicators and is better adjusted to NMR (p-value: 0.000, CI: -0.15; -0.07 and adj. R^2: 0.60). The association between the BFP and infant mortality rates is also important and is better adjusted to NMR (p-value: 0.001, CI: -9.18; -2.59 and adj. R^2: 0.60) and IMR (p-value: 0.000, CI: -7.43; -2.23 and adj. R^2: 0.74) than to U5MR (p-value: 0.020, CI: -6.72; -0.60 and adj. R^2: 0.71). Fertility is positively associated with IMR (p-value: 0.000, CI: 2.25; 4.12 and adj. R^2: 0.74) and U5MR (p-value: 0.000, CI: 3.00; 5.00 and adj. R^2: 0.71). Educational attainment is strongly associated with all infant mortality indicators with greater statistical significance for IMR and U5MR (NMR: p-value: 0.002, CI: -6.20; -1.50 and R^2: 0.60, IMR: p-value: 0.000, CI: -10.20; -4.07 and adj. R^2: 0.74 and U5MR: p-value: 0.000, CI: -11.59; -4.87 and R^2: 0.71). Live births by prenatal visits are only statistically significant for NMR (p-value: 0.000, CI: -2.58; -0.11 and adj. R2: 0.60). The safe water supply and sewage services coverage rates are not associated with any infant mortality indicator in the general model.

Table 4 presents the results of the estimations using household stratified by minimum wage, controlled by the other independent variables. An association between household income and NMR is confirmed for almost all income strata. This association is less significant for the highest household income stratum. There is no association between the highest stratum, above 20 minimum wages, approximately US$ 5,300.00 at 2015 US$ current prices, with IMR and U5MR rates (p-value: 0.135, CI: -64.58; 8.92 and adj. R^2: 0.73, and p-value: 0.594, CI: -55.12; 31.82 and adj. R^2: 0.70, respectively). It is worth noting that there is a signal inversion depending on the specific income strata and infant mortality rate. The signal is negative for the proportion of households below two minimum wages, suggesting that an income under this income bracket presents an increased risk for all infant mortality. On the other hand, an income over two minimum wages would function as a protective factor for infant mortality, except for IMR and U5MR in the highest-income strata. It is worth noting that for a household income between 2 and 5 minimum wages, the association between income and U5MR is weakly significant (p-value: 0.051, CI: -21.66; 0.03 and adj. R^2: 0.71).

Table 4 The relation between child mortality and income per household stratified by minimum wage

	NEONATAL MORTALITY				INFANT MORTALITY				UNDER-FIVE MORTALITY			
	Coef.	(95% CI)	R^2	p-value	Coef.	(95% CI)	R^2	p-value	Coef.	(95% CI)	R^2	p-value
% OF HOUSEHOLDS LIVING WITH AN INCOME ABOVE 20 MINIMUM WAGES	-53.44	(-90.09, -16 .77)	0.57	0.005	-27.83	(-64.58, 8.92)	0.73	0.135	-11.64	(-55.12, 31.82)	0.70	0.594
% OF HOUSEHOLDS LIVING WITH AN INCOME BETWEEN 10AND 20 MINIMUM WAGES	-27.60	(-42.86, -12.35)	0.58	0.001	-25.27	(-43.46, -7.08)	0.74	0.007	-34.40	(-66.86, -1.94)	0.71	0.038
% OF HOUSEHOLDS LIVING WITH AN INCOME BETWEEN 5 AND 10 MINIMUM WAGES	-11.87	(-17.86, -5.87)	0.58	0.000	-13.31	(-21.26, -5.36)	0.74	0.001	-17.25	(-29.67, -4.83)	0.72	0.007
% OF HOUSEHOLDS LIVING WITH AN INCOME BETWEEN 2 AND 5 MINIMUM WAGES	-6.94	(-11.99, -1.89)	0.57	0.008	-11.17	(-18.11, -4.25)	0.74	0.002	-10.82	(-21.66, 0.03)	0.71	0.051
% OF HOUSEHOLDS LIVING WITH AN INCOME BETWEEN 1 AND 2 MINIMUM WAGES	10.70	(5.00, 16.40)	0.58	0.000	9.46	(1.19, 17.74)	0.74	0.026	13.44	(3.05, 23.82)	0.71	0.012
%OF HOUSEHOLDS LIVING WITH AN INCOME BETWEEN 0 AND 1 MINIMUM WAGE	7.53	(3.90, 11.16)	0.58	0.000	9.16	(4.06, 14 .27)	0.75	0.001	8.87	(1.03, 16.71)	0.71	0.027

R^2 REFERS TO ADJUSTED VALUES

The relation between the employment rates and infant mortality can be interpreted as a confounding factor due to the relation between income and infant mortality rates. However, this possibility should be observed with caution, mainly because a considerable proportion of income refers to types of income other than wages, such as social programs and retirement benefits, profits,

interests, dividends, rents, and royalties. Also, estimations demonstrated that the signal of the relation between income and mortality rates may change, depending on the household income strata. It is hardly possible to suppose that the employment rate stratified by worked hours follows the same signal inversion in relation to infant mortality rates. Those findings suggest that employment and income have different impacts on child mortality.

We also conducted estimations using the total live births per year according to the number of prenatal visits in the population of women aged 15 to 49 and the proportion of physicians and nurses per thousand inhabitants (Table 5).

The number of live births is statistically significant for NMR only (p-value: 0.034, CI: -2.58; -0.11 and adj. R^2: 0.60). This association has a negative signal, denoting that the lower the number of prenatal visits in relation to the absolute number of live births the higher the efficiency of prenatal care. On the other hand, the availability of physicians and nurses is statistically significant for all infant mortality indicators, with a negative signal as well (p-value: 0.041, CI: -0.81; -0.02 and adj. R^2: 0.60 for NMR, p-value: 0.000, CI: -1.32; -0.54 and adj. R^2: 0.75 for IMR and p-value: 0.000, CI: -1.26; -0 .48 and adj. R^2: 0.72 for U5MR), denoting that the access to health professionals has an impact on all child mortality indicators, especially IMR and U5MR.

Table 5 The relation between the proportion of live births by prenatal visits and the proportion of physicians and nurses per thousand inhabitants and infant mortality

	NEONATAL MORTALITY			INFANT MORTALITY			UNDER-FIVE MORTALITY		
	Coef. (95% CI)	R^2	p-value	Coef. (95% CI)	R^2	p-value	Coef. (95% CI)	R^2	p-value
LIVE-BIRTHS BY PRENATAL VISITS	-1.34 (-2.58, -0.11)	0.60	0.034	-1.33 (-2.81, 0.15)	0.74	0.076	-0.93 (-2.48, 0.62)	0.71	0.233
NUMBER OF PHYSICIANS AND NURSES BY 1000 INHABITANTS	-0.42 (-0.81, -0.02)	0.60	0.041	-0.93 (-1.32, -0.54)	0.75	0.000	-0.87 (-1.26, -0.48)	0.72	0.000

R^2 REFERS TO ADJUSTED VALUES

The 33 models indicated that the multilevel panel data with fixed effects nested within-cluster based on observations grouped in regions with very different socioeconomic characteristics proved to be an efficient method for identifying and analyzing the determinants of infant mortality in Brazil.

The results show that in addition to the variables already known in previous studies to be associated with infant deaths, such as coverage of the BFP, per capita income and fertility rate [6, 24-26], other factors may have important effects on child mortality. The employment rate, educational attainment, quality of prenatal care and population access to health professionals are also elements impacting infant health from birth to 5 years old.

The results also suggest that a family income slightly higher than 2 minimum wages can make a difference in avoiding infant deaths. In contrast, it is also worth mentioning that those findings highlight the importance of the BFP to prevent child mortality, considering that a minimum financial improvement that can have a great impact as a protective factor for families living on much less than 1 minimum wage. The safe water supply and sewage services coverage rates were not associated with any infant mortality indicator. Those results will be discussed in the next section.

4.1.15 Discussion

The results of this study proved that the conceptual framework adopted, the CMHC, is a useful tool for the analysis of the effects of social determinants of health in an upper-middle-income country, but with distinct subregional characteristics, under the effects of an inclusive institutional, social and health policies framework. Those results were only possible with the use of the multilevel panel data model with fixed effects nested within-cluster. The method presented allowed the use of the variables provided by the conceptual framework by applying aggregated data that could hardly be used by other methodologies without leading to incorrect estimations. Our models were able to isolate the effects of the variables under study from factors not observed, which are subject to estimation errors due to different degrees of error homogeneity within and between clusters.

Although other studies on infant mortality in Brazil relied on larger datasets for the analysis of the factors impacting infant mortality in Brazil after the implementation of FHS and BFP, our models relied on a longer observational window that allowed us to infer more about specific factors related to infant mortality rates such as the relation between the employment rate and different indicators of infant mortality and between the BFP and the neonatal mortality rate or the threshold of household income according to minimum wage bracket which acts as a protective factor for infant mortality. Furthermore, the use of the methodology of clustered observations at different levels of fixed effects is a low cost-benefit solution, since it relies on a small volume of data when compared to conventional panel data studies.

In this section, we will address each of the variables and their relationship with mortality rates and conduct the analysis in line with CMHC.

Employment and infant mortality

Regarding the health capabilities approach, the findings may be interpreted as a possible effect of employment on the childbearing decision as part of reproductive choice at the household level, which may be a result of a reasonable period of increasing employment that impacted a substantial number of households and therefore neonatal mortality that represents more than 70% of all infant mortality rates. On the other hand, the association between a one-year time lag of employment rate and IMR that represents almost 90% of the total U5MR [49], may be related to a better socioeconomic condition and the household ability, or freedom, to child-caring, feeding, identifying an emergent health issue and searching for best treatments for death prevention.

Few studies have addressed the relation between employment and unemployment and infant mortality in Brazil. In a study using a panel data over populational health and economic downturn in Latin America, Williams *et al.* [50] found that besides income and inflation, unemployment is also strongly related to under-5 mortality. Although the authors reported that unemployment data in Brazil were not available for the study period (1981 to 2010). In a mixed study with data based on interviews collected in a small town near São Paulo, Ventura *et al.* [51] concluded that among adults who lived in the same household, the fact of having or not having a job was an important factor in determining the degree of stability and vulnerability of families, which is not in disagreement with the capabilities approach.

Income and infant mortality

Changes in the income signals according to strata and different effects on infant mortality may be related to the association between income and access to health services. The change of signal above two minimum wages stratum suggests that the higher the proportion of families earning up to 2 minimum wages on average (about US$ 525.00 in 2015 at current prices), the higher infant mortality tends to be, except for infant mortality (IMR) and under-five mortality (U5MR) and stratum “A” household income, that are not significantly associated. Therefore, a household income of less than two minimum wages increases the odds of infant death and a slight improvement in household income over 2 minimum wages may have a considerable impact on infant mortality in all age brackets.

Such results suggest that an income threshold above two minimum wages per household provides more freedom to prevent infant deaths.

In a geospatial study on the inequality of infant mortality in Brazil, conducted between 2006 and 2010, Oliveira *et al.* [26] concluded that low household income, fewer prenatal visits and fewer neonatal intensive care unit beds are correlated, forming a cluster in the North and Northeast macro-regions of the country.

Bolsa Família Program and infant mortality

Our findings are in accordance with the results of other studies. Many authors have highlighted the importance of the BFP in reducing socioeconomic inequalities that hinder the access to primary healthcare provided by the FHS and improving nutritional status with positive effects on infant health and mortality [5, 25, 28].

Nevertheless, some studies show that the interaction between the BFP and the Family Health Program (FHP) is associated with higher average prenatal visits only in the Northeast states [28] and that the BFP has little or no impact on neonatal mortality [6]. Other studies confirmed the impacts of BFP on IMR and U5MR [5, 25]. Those findings are somewhat controversial, considering that another study pointed that increased neonatal mortality in the Northeast macro-region between 2006 and 2010 was linked to lower numbers of prenatal visits and socioeconomic conditions [26].

An aspect to be considered when analyzing those differences is that our study was conducted over a 12-year period after the implementation of the BFP and that those studies were conducted over shorter periods, from 5 to 7 years after the implementation of the BFP [6, 25] or in ecological analysis with predefined periods or over a single period [5, 25]. Our observational window may have identified different effects of BFP coverage over time, with important impacts on neonatal mortality as well, which is consistent with a higher number of prenatal visits.

A study pointed out that in 1990 post-neonatal mortality (infant deaths occurred between the 28th to 364th day of life) represented about 44% of the total U5MR, while in 2015, early neonatal mortality (ENMR: infant deaths occurred between birth and the seventh day of life) was the main component of child mortality in Brazil, representing 41% of total deaths [49]. Thus, the findings suggest that there have been changes regarding the age structure of child deaths in recent years.

Prenatal visits, access to health professionals, and infant mortality

Another point that may explain differences in previous studies regarding the controversy of increased or decreased prenatal visits in the Northeast states and neonatal mortality, is the fact that the number of live births per prenatal visits, as a proxy of the quality of prenatal care provided, is

statistically significant for neonatal mortality only. In this sense, there may be a confounding factor involving the results of previous studies, considering that not only the number of prenatal visits, but also the quality of care provided emerges as a major factor in determining neonatal mortality. Our results are in line with a study that stresses the importance of prenatal quality for neonatal mortality [52].

Studies have related neonatal mortality with perinatal causes and, although prenatal care represents a protection factor, mortality is strongly associated with the availability of primary care physicians [24]. In this sense, in our methodological proposal, we considered the overall access to health professionals; physicians, and nurses; as a proxy of the access to comprehensive healthcare. Our findings suggest that in addition to prenatal care, access to health professionals is substantially related to all infant mortality indicators and is better adjusted for IMR and U5MR.

Fertility rate and infant mortality

The fertility rate was significant for infant mortality and under-five mortality rates. As mentioned in the Method section, this covariate was used as a control variable but also, under the perspective of the capabilities approach, indicates the ability of the household to make reproductive choices. Our results are supported by Barufi *et al.* [53]. In a quantitative study based on municipal data from 1980 to 2000 in Brazil, the authors indicated that as socioeconomic inequalities such as income and women illiteracy grow, infant mortality also tend to increase and that would be related to adolescent fertility rate that is positively associated with IMR, suggesting that family planning can help to reduce infant mortality. This aspect is very relevant since adolescent mothers are responsible for more than 20% of infants born in Brazil [54] and that there are clusters of adolescent mothers in the North (including Mato Grosso state and Legal Amazon) and the Northeast macro-regions of the country [26].

Our findings are also consistent with studies that have reported a decline in fertility rates accompanied by declines in illiteracy rate and socioeconomic improvements, all related to declines in under-five mortality rates [23, 25, 28, 52]. However, these results should be examined with some caution, since the literature shows that there are conflicting results regarding the association between the birth rate and infant mortality. Reductions in infant mortality and improvements in socioeconomic indicators may hide confounding factors linked to the fertility rate, such as increased female labour market participation, income and education [55].

Educational attainment and infant mortality

The relation between our dependent variables and educational attainment was statistically significant in all estimations. Educational attainment in our models was applied to evaluate the capacity of households to convert capabilities into functionings.

As part of a criticism formulated by Tengland [20] regarding what the author interprets as a political liberalism conception of health capabilities approach proposed by Sen [18] and Nussbaum [16], job seeking, reproductive health and reproductive choices, as well as education capabilities are part of health as a holistic multi-dimensional phenomenon. Thus, measuring health functioning (infant mortality for instance) is the same as measuring education attainment or employment.

This statement seems to take the capabilities approach to an extreme, however, when exploring the individual's capabilities, Tengland puts the development of competences as depending on a basic degree of education and special training. In this line, Nussbaum states that as fundamental capabilities, every individual, at least when he or she comes of age, has to be equipped with a decent degree of health and primary and secondary education. In addition, Tengland also stresses that capabilities, in fact, the actualization of capabilities into functionings, is not an excluding or concurrent process. It is possible, and in fact, desirable, for one to actualize multiple capabilities simultaneously, although in some cases some capabilities are not turned into functionings. Thus, it is logical to expect that among households, the capabilities approach suggests that there might be differences concerning their motivation for educational attainment, family planning, and job-seeking as outcomes of the interaction of the dimensions proposed by Ruger, given individual internal characteristics.

This reasoning may also be supported by an apparent contradiction in Nussbaum's statement regarding her conception of capabilities as plural elements of the quality of life of individuals. Nussbaum stresses that capabilities are qualitatively distinct, such as integrity and bodily health, or education, among other aspects, considered as indivisible and not reducible to a simple metric without distortion. Probably in this statement, Nussbaum was referring to empirical studies aiming to synthesize well-being and happiness in a single scale. In this regard, Anand conducted a study aiming to test the operationalization of variables according to the capabilities approach proposed by Nussbaum based on secondary data from the British Household Panel Survey. The study found evidence suggesting that a wide range of capabilities had a statistically significant association with

well-being. The study relied on secondary data sources and subjective well-being concepts according to a scale of life satisfaction from 1 to 7 [56].

Continuing with Nussbaum, the key question to ask when comparing societies is "what is each person capable to do and to be in terms of opportunities?" This reasoning is in line with Tengland's vision of capabilities as a holistic multi-dimensional phenomenon. Thus, capabilities may be assessed by health and educational attainment at an aggregated level if one intends to assess or to propose public policies aiming to promote a fruitful environment that allows a constant actualization of capabilities. The list of basic capabilities proposed by Nussbaum implies the idea of what the State can do in this sense [16, 20].

Water supply, sewage services, and infant mortality

Although the lack of a statistically significant association between safe water supply and sewage services and all infant mortality indicators is a controversial result in relation to other studies that found an association between those factors, it is worth noting that most of those studies relied on interpolated data from long periods after the 2000 Census or data covering only part of the municipalities of the country, which may not reflect the evolution of socioeconomic data linked to the sanitary infrastructure.

A study of Guanais based on data of 4853 municipalities of Brazil between 1998 and 2010 found a strong negative association between water supply coverage and infant mortality [28]. That study applied interpolated techniques to obtain data between the National Census from 2001 to 2009, excluding from the analysis a considerable number of municipalities located in rural areas in the North macro-region of the country (n=449) due to the unavailability of socioeconomic data until 2003 [32]. Rasella, in a longitudinal panel data study on the effects of FHS and BFP, used inadequate sanitation coverage as a control variable that encompasses safe water supply and sewage services together [25]. The study was conducted over a three-year period, 2006-2009, with 2853 municipalities of a total 5565, based on interpolated socioeconomic data from the 2000 National Census.

Another possibility for explaining the lack of association between sanitation and water supply and infant mortality indicators may be related to the fact that structural socioeconomic variables change slowly over time in relation to other socioeconomic variables and the changes regarding water supply and sewage services were probably not captured by our model.

We must emphasize that our data related to safe water supply and sewage services coverages are somewhat redundant, as the sum of coverage rates of urban and rural areas exceeds 100%, which suggests that there must exist redundancies in water supply and sewerage systems and/or overreporting errors that must be considered when interpreting our results.

The health capabilities approach and infant mortality in Brazil

In specific contexts, such as extreme poverty, Sen suggests that one should consider a relatively limited number of central and important functionings and corresponding basic capabilities (such as the ability to be well-nourished and sheltered or escaping from premature death). In other contexts, the number of capabilities and functionings could be much higher and more diversified. One must choose what are the relevant functionings in a specific context and what might be considered negligible [19].

The list of basic capabilities proposed by Nussbaum is far longer than those of our study proposal. Although Tengland reduced this list to a central set of capabilities [20] our methodological proposal restricted those possibilities to the factors interacting with the social and health policies recently implemented in Brazil, to the specificities of the country and data availability.

Tengland's perspective of health regarding the definition of health capabilities is dynamic in the sense that although some capabilities are impossible for one to convert into functionings, health capabilities must be actualized or turned into functionings. This perspective of health capabilities is more in line with the concept of capability proposed by Nussbaum, for whom capabilities, other than functionings, may be listed as State priorities of actions that may allow individuals to exercise the freedom to choose the life they want to live. On the other hand, for Sen, there is no room for one to define capabilities priorities, and goals. Taking this into account, although Ruger did not make any reference to Nussbaum's conception of capabilities, the CMHC, and its perspective of health capability as the result of State paternalism and agency seems to be more aligned with a pragmatic perspective of the capabilities approach, having functionings as the "results" to be measured [20].

This study has several strengths. To our knowledge, this is the first study to use the CMHC to study the determinants of infant mortality. The second strength of this study lies in a multi-level data panel with fixed effects nested within-cluster to use aggregate data nested within macro-regions to study the determinants of infant mortality. Third, this is the first time the employment

rate is used as an independent variable associated with infant mortality in Brazil. Finally, this study used the longest observational period after the implementation of the BFP in 2003.

Study limitations

Despite those strengths, this study also has limitations that must be considered when interpreting the results. First, in the application of the CMHC, we were unable to operationalize a variable to control individual characteristics. After conducting a scoping review, we concluded that, in Brazil, regional inequalities can lead to contradictory results such as advanced maternal age as a protective factor for low birth weight. In some regions of the country maternal age conflicts with the level of maternal education. This creates a confounding factor in specific regions of the country. It is a phenomenon known as the "Low Birth Weight Paradox" [57]**.** On the other hand, we have not found, nor have we been successful in developing a proxy that could be used as a control for the internal dimension in the CMHC. Second, the CMHC was designed to operationalize variables at the individual level and our approach was designed based on aggregated data at the state level. As there is no data available on the employment rate at the municipal level, we use aggregated data at the state level, which can generate a limitation. Although our results are consistent with findings in other studies, the risk of ecological fallacy cannot be ignored, especially with regard to the effects of the variables analyzed at the household level, such as the birth rate and family planning. Third, as we have mentioned in the "Independent Variables" section we applied interpolation techniques for specific periods of our independent variables. Although those are minor interpolations and estimations, they must be taken into account when interpreting our findings. Fourth, in some states, the total coverage of safe water and sewage services exceeds 100%, suggesting the existence of overreporting or more than one contract per household, which should be considered when interpreting the results. Fifth, although the quality of infant mortality information has recently improved in the North and Northeast regions, underreporting still occurs, mainly regarding rural areas and municipalities with small populations, and must be taken into account when interpreting the results of the present study as a possibility source of bias. Finally, there are some limitations regarding the external validity of our study due to the specificities of Brazil. Although the World Bank classifies Brazil as an upper-middle-income country [58], it ranks 73rd in terms of per capita income. The country has a population of about 212 million living in the world's fifth-biggest territory and is the only Portuguese-speaking country in the Americas.

Although in terms of absolute GDP value, Brazil ranked eighth in the world in 2018, economic inequalities in the country have reached extreme levels and are one of the worst in the world

4.1.16 Conclusions

The results of this study showed that the CMHC is a useful tool for the analysis of the effects of social determinants of health in an upper-middle-income country with distinct subregional characteristics, under the effects of an inclusive institutional, social and health policies framework. Our results were only made possible by using the multilevel panel data model with fixed effects nested within-cluster. The method allowed the use of the variables provided by the conceptual framework based on aggregated data that could hardly be used by other methodologies without leading to incorrect estimations. The estimations could isolate the effects of the variables under study from factors not observed, which are subject to estimation errors due to different degrees of error homogeneity within and between clusters.

Our models covered a longer observational window that allowed us to infer more about specific factors related to infant mortality, such as the relation between the employment rate and different indicators of infant mortality and the BFP and the neonatal mortality rate or the threshold of household income according to minimum wage bracket which acts as a protective factor for infant mortality.

Furthermore, the use of the methodology of clustered observations at different levels of fixed effects is a low cost-benefit solution, considering that it relies on a low volume of data when compared to conventional panel data studies.

Declarations

Ethics approval and consent to participate

Not applicable. The present study does not require ethical approval or consent for participation, since it was based on aggregated data at the population level and in the public domain that is freely accessible.

Consent for publication

Not applicable. The present study did not use humans and animals.

Availability of data and materials

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Competing interests

The authors hereby declare that they have no competing interests.

Funding

A. Bugelli was supported by CAPES Foundation (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, Ministry of Education of Brazil, Brasilia – DF 700040-020, Brazil – Science without Borders Program – proc. 12940/13-5) and by FESP (Faculté d'Études Supérieures – ESPUM – École de Santé Publique de l'Université de Montréal).

Authors' contributions

All authors contributed to the theoretical basis of this study. The statistical analysis was conducted by A. Bugelli under the supervision of R. B. Da Silva and C. Sicotte. All authors contributed to the discussion and interpretation of results. The final manuscript was read and approved by all authors.

Acknowledgements

The research reported in this article is part of A. Bugelli's doctoral (Ph.D.) thesis at École de Santé Publique de l'Université de Montréal - ESPUM.

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Chapter 5 Discussion

This chapter is organized into 5 subsections. The first subsection summarizes the main results of the three research papers in relation to published studies. In the next subsection we discuss the results in light of the SDH and the capabilities approach. In the third subsection , we highlight the contribution of our findings to the discipline under study and report the limits of this study. In the following subsection we present recommendations for public policies that could reduce child mortality in Brazil in a longer-term perspective. This discussion finally ends with the avenues of research to be explored for the future.

Summary of results

The overarching goal of this dissertation was to identify the determinants of infant mortality in Brazil after the implementation of the FHS and BFP with a view to raise plausible hypotheses for the slowdown, the regional disparities and the anomaly in the of the trend of declines in the IMR in Brazil. To respond to this general goal, we conducted three studies aiming at the following specific objectives:

1: Identifying and summarizing the determinants of infant mortality in Brazil based on a scoping review, to raise hypotheses for the recent changes in the infant mortality rates in Brazil and identifying gaps in terms of research concerning the determinants that may impact infant mortality in Brazil based on the CMHC;

2. To conduct a descriptive and retrospective analysis of the determinants of infant mortality in Brazil between 2004 and 2015, based on the model of WHO's CSDH framework aiming at analyzing the evolution of these determinants to understand the behavior and disparities of IMR observed in recent years in the country.

3.To perform a multilevel panel data analysis as a methodological proposal to identify the factors impacting mortality in Brazil according to the CMHC, aiming at raising plausible hypothesis to explain the behavior and the disparities of infant mortality observed in recent years in Brazil, after the implementation of FHS and *Bolsa Família* programs.

The results of these studies demonstrated that in the light of the CMHC and the social determinants of health, regional disparities related to inequalities in factors such as income, education, employment, fertility rate, access, and quality of health services, account for inequalities in infant mortality rates, especially in the north and Northeast macro-regions of the country, which likely hamper further reductions of infant mortality. Those inequalities would explain both the slowdown

in the reduction and the tendency of the infant mortality rate to remain at relatively high levels. Results also demonstrated that variations in those factors for reasons relating to the economic and political crisis, likely have interrupted the secular trend of declining infant mortality rates. In this regard, results suggest that a sharp reduction in employment rate observed between 2014 and 2015, among other factors, may have had a delayed impact on IMR in 2016. The results also identified an association between employment and different infant mortality indicators, with employment rate possibly impacting infant mortality up one-year, under-five mortality up two-years and neonatal mortality up three-years at least. Finally, and not least, studies have shown that there is a household income threshold that acts as a protective factor against child mortality, below which the greater the proportion of households below this income bracket, the greater the risk of an increase in child mortality.

In the first paper, in addition to the factors mentioned above, living conditions linked to housing were identified as a factor impacting infant mortality as well. This study also revealed that although the implementation of the SUS the FHS and BFP have proved to be important infant mortality reducers, some limitations relating to inequalities in the access to quality and comprehensive health services seem to have important implications for reducing infant mortality rates. These findings shed light on the limited capacity of social and health policies in promoting sustainable reductions in infant mortality in Brazil, mainly in the presence of socioeconomic inequalities. This paper also identified a gap in terms of studies on a possible direct relationship between employment and infant mortality.

Our results are in accordance with another systematic review that reported that life conditions according to socioeconomic indicators such as income (as a distal factor), housing, basic sanitation and accessibility to health were identified as determinants of post-neonatal deaths due to reducible causes. This review also highlighted the existence of health and socioeconomic inequalities in the North and Northeast regions (Ferrari Rosângela Aparecida Pimenta 2012). Duarte (Duarte 2007), summarized research studies from 1998 to 2006, aiming at assessing how Brazilian literature analyzed the infant mortality trends and possible associations with changes in the organization and financing of SUS. The review concluded that the impact of assistance and health measures on child mortality is limited, causing a reduction to a level that tends not to be exceeded unless they affect existing social inequalities. Another systematic review conducted by Santos (Santos 2010) identified the main risk factors for infant mortality and the causes of death between 1980 and 1983

as well as between 2005 and 2008. In the first period, the main risk factors for infant mortality reported were related, largely, to socioeconomic characteristics and, in the second period, to the newborn, to maternal and child healthcare and socioeconomic characteristics. This study concluded that if in previous decades the priority was to solve problems linked mainly to the physical and social environment where the child lived, in the second period the challenge incorporated the need to build equity in access to qualified health services, together with public policies aimed at reducing socioeconomic inequalities and increasing basic sanitation. Findings also pointed in-hospital infant mortality as a consequence of multiple factors, highlighting deficiencies in the quality of prenatal care, care at birth and during the newborn's stay in highly complex services.

In the second study, we identified a declining trend of IMR in all regions of the country, although inequalities in infant mortality were observed in the North and Northeastern states. Findings point out that these inequalities in infant mortality are related to disparities in the distribution of SDH and health-related factors. The results also suggest that these disparities limit further reductions in infant mortality, which would probably explain both the slowdown in the reduction and the tendency of the infant mortality rate to remain at relatively high levels.

Studies carried in Brazil between 2000 and 2010 based on ecological approaches confirmed the existence of disparities in infant mortality, with higher rates observed in the North, Northeast and Midwest states, linked socioeconomic and living conditions. Mendes *et al.* (Mendes, Ribeiro Hda, and Mendes 2013) associated the greatest reduction of infant mortality in the northeast macro-region to reductions of socioeconomic inequalities related to income, malnutrition and diarrheal diseases, although the infant mortality rate in these regions remained higher regarding others. In another study, Oliveira *et al.(Oliveira et al. 2013)* found a correlation between neonatal mortality, forming clusters in North and Northeast states, with low per capita household income, less prenatal consultations and neonatal ICU beds. Findings suggesting an association between income and infant mortality are also described in the literature (Oliveira et al. 2013; Mendes, Ribeiro Hda, and Mendes 2013; Martins, Pontes, and Higa 2018). Garcia in a study conducted in Brazil between 1993 and 2008 reported that income affected infant mortality but to a lesser extent over time (Garcia and Santana 2011). The association between the coverage rate of BFP and infant mortality has been rather explored (Shei 2013), particularly when associated with increases in the coverage rate of FHS (Rasella et al. 2013; Guanais 2013). Studies also demonstrated that quality (Almeida

W. da and Szwarcwald 2012), inequalities in the access of health services (Araujo, Goncalves, and Machado 2017) and availability of primary care physicians (Russo et al. 2019) are factors influencing infant mortality, which is congruent with our results regarding the quality and the access to health services. Inadequate sanitation was used in a study on BFP by Rasella *et al.* (Rasella et al. 2013) as a control variable and was inversed associated with infant mortality. Few studies have addressed the possible association between employment or unemployment and infant mortality rates in Brazil. In a study using data panel over populational health and economic crisis in Latin America, Williams *et al.* [43] reported that unemployment is related to under-5 mortality, although the authors reported that unemployment data in Brazil were not available for the study period (1981 to 2010). In a mixed-method study based on interviews building on data collected in a small town in the Metropolitan area of São Paulo, Ventura *et al.* (Ventura, 2003) found that among adults who lived in the same household, the fact of having or not having a job was an important factor in determining the degree of stability and vulnerability of families with effects on infant mortality, which is in line with our findings.

A possible effect of employment on infant mortality rates may raise questions about which theoretical foundations employment or unemployment may be related to infant mortality. Dallolio *et al.* (Dallolio 2012) in an ecological study on the factors associated with infant mortality in Italy, concluded that although Italy is a high-income country with universal access to health care, the variability of IMR was strongly associated with relative and absolute income and unemployment rate. The study found that unemployment was the only variable independently associated with infant mortality in a multiple stepwise linear regression. According to these authors, the challenge for reducing inequalities in IMR among Italian regions is to promote economic growth and increase employment. The theoretical basis for this study to support the hypothesis that unemployment is directly and independently associated with infant mortality is found in the studies made by Janlert & Hammarström (Janlert and Hammarström 2009). After conducting a cohort of 1,000 school-leavers for 14 years, the study identified seven different models to explain the effect of unemployment on health: an economic deprivation model, a lack of control model, a locus of control model, a stress model, a social support model, a work involvement model and a model of latent functions. The model of latent functions was the most successful for explaining the relation between unemployment and health, followed by the economic deprivation model. In short, the latent functions model sustains that work contributes to latent functions as giving a day time

structure, providing opportunities for social contact, status, and personal identity, striving for collective purposes and sharing experiences. According to other authors, the association between socioeconomic factors such as education, income and employment, and health outcome is related to the capacity of these factors in shaping health-related behavior (Braveman and Gottlieb 2014; Stringhini et al. 2010). Both explanations are not incompatible with those of the capabilities approach, having the employment as a conversion factor of capabilities.

In the third and last paper, the study proved that the CMHC is a useful tool for the analysis of the effects of social determinants of health in an upper-middle-income country with distinct subregional characteristics, under the effects of inclusive institutional, social and health policies framework. Results showed that in addition to the variables already known in previous quantitative studies to be statistically associated with infant deaths, such as coverage of the BFP, per capita income and fertility rate (Shei 2013; Rasella et al. 2013; Rasella, Aquino, and Barreto 2010b; Guanais 2013), other factors may also have important effects on child mortality such as employment, educational attainment and the access and quality of health services (Araujo, Goncalves, and Machado 2017; Malta et al. 2019; Almeida W. da and Szwarcwald 2012). Our estimations did not find any association between water supply and sewerage services coverage rates and any infant mortality indicators. Findings also suggest that a family income slightly higher than 2 minimum wages can make a difference in avoiding infant deaths. In contrast, a household income of less than two minimum wages increases the odds of infant death. It is also worth mentioning that those findings highlight the importance of the BFP to prevent child mortality, considering that a minimum financial improvement can have a great impact as a protective factor for families living on much less than 1 minimum wage.

The results of this thesis showed that regional disparities related to inequalities in socioeconomic and health-related factors are likely the causes of inequalities in infant mortality rates in the North and Northeast macro-regions of the country. These inequalities proved to be quite rigid over time, which could also explain the slowdown and the tendency to stabilize infant mortality rates at still high levels.

Brazil is classed as an upper-middle-income country and although in terms of absolute GDP the country ranked eighth in the world in 2018, it only ranked 73rd in terms of per capita income. Brazil has a population of about 212 million living in the world's fifth-biggest territory and is the only Portuguese-speaking country in the Americas. Economic inequalities in the country have

reached extreme levels and are one of the worst in the world. In addition to these specificities, the scarcity of recent studies on other upper-middle-income countries with similar characteristics hampers the comparison of our results with studies of other countries.

A case study based on interviews, qualitative and quantitative data conducted in Peru, another Latin American upper-middle-income country with wide social and regional disparities, analyzed the effect of an antipoverty political agenda on child health and nutrition between 2000 and 2013 (Huicho et al. 2016). The study emphasizes the progress obtained in reproductive, maternal, neonatal, and child health in Peru. The country holds the second-highest rate of reduction in U5MR (6.2% reduction per year, down to 17 per 1000 live births in 2015). Recently Peru was ranked the first among low and middle-income countries in the reduction of early neonatal mortality. The country also achieved to halve the number of children underweight although stunting prevalence remained stable about 30 to 40% of children under-five years between 1992 and 2007.

The study examined the outcome of social and health intervention coverage, under-five and neonatal mortality, and prevalence of under-five stunting in relation to social determinants of health such as economic growth, poverty, unmet basic needs, urbanization, women's education, water supply, fertility rate, and child nutrition. Those health interventions were implemented as part of a set of multisectoral antipoverty programs, including the CCT *JUNTOS*, which was intended to break the intergenerational poverty cycle via increased access to education and health services, and the *Seguro Integral de Salud* (SIS), a comprehensive health insurance system. These achievements were largely attributed to the political transition to democracy that encouraged a broad process of participation, with a strong political will towards macro-policies aiming at improving health and alleviating poverty. Regarding the exceptional results in terms of early neonatal mortality, this is largely attributable to the increased coverage of health services, improved equipment supply, and deployment of trained health professionals with the emphasis on the poorest states, along with economic growth and progress in the social determinants of health.

Despite all those progress, Peru is still a long way from assuring universal, equitable and effective coverage of interventions aiming at maternal and child health. The U5MR is still about twice as high as that in Chile, and the prevalence of stunting is twice as high as that in Brazil. Among the challenges reported as bottlenecks to further improvement in maternal and child health, the study points out the reduction of inequalities in wealth distribution, poverty, and access to basic services, especially in the Amazon and Andean rural areas that remain as important problems, enable health

services to face more complex causes of maternal, newborn, and child deaths, including the management of pregnancy complications and the provision of neonatal intensive care, strengthen efforts to tackle systematically the problem posed by unsafe abortions, adolescent pregnancies, and maternal deaths, and adapt health services to cultural diversity and the specific needs of indigenous communities.

The issues raised in the Peruvian study and ours highlight some possible bottlenecks common to upper-middle-income Latin American countries that adopted a multisectoral perspective based on the social determinants of health, aiming at improving maternal and child health (de Andrade et al. 2015). The effort deployed in the implementation of health and social policies targeting universality and comprehensiveness under the presence of inequalities unveils the weak links of that perspective. Concerning to the provision of health services, if these efforts have not succeeded in satisfactorily achieving both universality and integrality, in relation to the effective use of services, socioeconomic inequalities generate inequalities in access to health and food security and may perpetuate health inequalities.

Although there are no studies aiming at explaining the recent changes in the infant mortality rates in Brazil, our results find echo in a study based on estimations from the Burden of Disease study focused on identifying the leading causes of child mortality in Brazil in 1990 and 2015 (França et al. 2017). Results showed that despite the notable decrease in under-five mortality between 1990 and 2015, the most of deaths still occurred in the first year of life in 2015. The two top death causes were prematurity and congenital anomalies, the former corresponding to the main death cause in the states of North and Northeast macro-regions, and the latter as the main death cause in the Midwest, South and Southeast macro-regions. Both death causes are related to prenatal and child-birth care (Shei 2013; França et al. 2017). What draws the most attention, and which to some extent is in line with our findings, is that this study highlighted that in all states in the North and Northeast macro-regions, malnutrition was still among the top ten causes of mortality in children under five in 2015, a factor closely related to income and living conditions (Ramalho et al. 2013; Buhler et al. 2014). Also, between 1990 and 2015, deaths attributable to diarrhea dropped from the second leading to the seventh position among preventable causes, reinforcing that environmental factors related to housing may have been losing relevance to child mortality over time.

Despite many debates that have emerged in the wake of the unexpected increase in under-one and -five mortality in 2016, to date, no study has attempted to explain the recent changes in infant mortality rates in Brazil. Much has been speculated about a possible deterioration of socioeconomic conditions, but without producing any evidence in this regard (Observatório de Saúde da RMSP 2018; Abrasco 2018). Although our data are insufficient to provide a full explanation for the anomaly in the downward trend of child mortality, our results showed that in addition to all the factors discussed above, a significant drop in employment between 2014 and 2015 emerges as a factor that may have had a delayed impact on under-one and -five mortality in 2016.

The SDH and the capabilities approach

Health inequalities have been widely studied building on various socioeconomic indicators. Researchers in European countries relied more upon occupational and social class, whereas others relied more upon income and education (Lahelma et al. 2004).

According to Sen, poverty is better understood as a capability failure since it involves heterogeneous failures of opportunity that are not fully correlated to income. People living in poverty have difficulty in converting income into functioning, thus income may not be a good proxy for capability, since it is the means for expanding capabilities and not the end (Nevile 2007; Nussbaum 2013).

Our results point to the existence of a threshold below which household income represents an additional risk of infant mortality and that above this threshold the risk is lower. What arises as an underlying factor in our analysis is that although this "threshold effect" seems to challenge a possible dose-response effect regarding income and social class, such as proposed in the social gradient concept (Marmot, Stansfeld et al. 1991, Marmot 2015), one must also consider the possibility that in a context of marked socioeconomic inequalities, flaws in the social gradient's structure likely point to other social inequalities, as inequalities in educational attainment. In this regard, Nussbaum categorically places education, in schools, in family or social programs, as a fertile functioning, central to addressing disadvantage and inequality, since people who received even only basic education have greatly enhanced employment options, chances for political participation and to interact socially and productively (Nussbaum 2013). This last aspect reinforces the idea that it is possible to evaluate capabilities in terms of functionings, as suggested by

Tengland (Tengland 2020). In this sense, Nussbaum states that regarding the basic capabilities, any individual must come of age with a decent level of health and having at least primary and secondary education. On the other hand, Tengland states that updating capabilities in functionings is a non-exclusive process, quite the contrary, it is desirable that individuals update their maximum capabilities and that the results to be observed are functionings. In the very roots of the capabilities approach, Sen posits that substantial freedoms are a set of (usually interrelated) opportunities to choose and to act (Nussbaum 2013). All of these observations allow us to conclude that it is possible to measure capability at the aggregate level, and that child mortality and educational attainment are the two sides of the same coin.

In the light of the capabilities approach, our results showed that low child mortality is accompanied by high levels of educational attainment and employment and that education is not only a means of providing greater income but is the triggering element of other capabilities and therefore functionings. This leads to that investment in education, and not only in new health technologies and/or in the health service system, is fundamental for the reduction of social and health inequalities.

The capabilities approach goes beyond a theoretical framework that places satisfaction as a basis for measuring how socially and economically developed is a society. This theoretical framework provides analytical instruments and categories for assessing individual well-being and social structures grounded on human rights and social justice, which allows an analysis of these structures regardless of their degree of development.

Ultimately, by proposing to analyze the changes in the behavior of infant mortality rates in Brazil, supported by the CMHC, we took up the challenge of developing a statistical model building on homogeneous variables that could, minimally, provide some clues about the causes of these changes. The results went beyond our expectations, although we recognize that all models have limitations since they represent only some aspects of the object of study. More research is needed to elucidate the pathways in which social determinants of health affect infant mortality.

Contributions and limitations of this thesis

5.1.1 Scientific contributions to the state of knowledge

The current thesis aimed at researching the determinants of infant mortality in Brazil to raise plausible hypotheses for the slowdown, the regional disparities and the anomaly in the trend of

declines in infant mortality rates in Brazil. The current state of knowledge of the determinants of infant mortality in Brazil has mainly been focused on social and health interventions and characterized by the use of social factors as control variables. This dissertation offers an innovative analytical and methodological approach, contributing to filling existing gaps in regard to the SDH in Brazil.

These contributions begin by updating the knowledge concerning the determinants of different infant mortality rates in the last ten years in Brazil. Although the concept of SDH is largely debated in the literature, it has been very challenging to identify and to operationalize variables to unveil the mechanisms by which these determinants may affect the population's health. Our scope review innovates by identifying and assessing those determinants under the perspective of the capabilities approach that seems to properly adapt to the context of an upper-middle-income country.

The adoption of such a theoretical framework is also challenged by the very nature of the current mainstream of the capabilities approach, which suggests that there are limitations for studies involving homogeneous variables as the means to assessing capabilities and their surrounding categories. In this regard, our third study also contributes to the field of the SDH with an innovative quantitative longitudinal approach that combined a multilevel panel data model with fixed effect nested within-cluster, using variables based on aggregated data, according to the CMHC. The results of this study showed that the CMHC is a useful tool for the analysis of the effects of SDH in an upper-middle-income country with distinct subregional characteristics. Our results were only made possible by using this methodological approach. The estimations isolated the effects of the variables under study from factors not observed and allowed us to infer more about specific factors related to infant mortality rates such as the relation between the employment rate and different indicators of infant mortality and between the BFP and the neonatal mortality rate.

Our findings also contribute to the existing literature about socioeconomic inequalities. The current knowledge of social determinants of health regarding socioeconomic inequalities, specifically regarding health outcomes as a result of a social gradient and income inequalities (Wilkinson and Pickett 2006; Marmot et al. 1991). Studies on these subjects have been conducted aiming at identifying and assessing the impacts of living conditions, income inequalities, and social class on health, stemming from debates involving mature socioeconomic contexts. Our results showed that the income inequalities related to infant mortality in Brazil are characterized by a dividing line in

which a threshold of up to two minimum wages increases the odds of infant mortality, whereas a household income over this threshold acts as a protective factor. This result draws attention to the fact that there is a considerable part of the Brazilian population that is vulnerable to infant deaths and that is not covered by any social program. Another aspect to be considered is that, under the hypothesis of prolonged periods of economic crisis, an increase of the proportion of households living below that threshold may substantially impact all infant mortality rates.

5.1.2 Limitations of this thesis

First, we acknowledge that the use of secondary data may often be subject to inaccuracies associated with large data collections, and the risk of ecological fallacy that may introduce bias in our estimations. However, demographic data provided by IBGE are widely used by international organizations such as the World Bank and the Inter-American Development Bank, under the "Fundamental Principles of Official Statistics" stablished by the United Nations Statistical Commission in 1994 (IBGE 2021; UN 2014). With regard to health-related data provided by the Brazilian Health Ministry, data and information follow the average data reliability of many developed countries and rank among the most reliable in Latin America according to studies and reports conducted by WHO and PAHO (Mathers 2005; FIOCRUZ 2006). Second, another aspect to be considered when interpreting our results is that the macro/social/economic approach adopted in the present dissertation cannot elucidated the "black box" of the effects of public policies on proximal determinants of infant mortality. We have adopted a different perspective, a macroeconomic perspective, that allowed us to apply in an original manner the Conceptual Model of Health Capability (CMHC) to an important public health problem in Brazil, the anomaly in the trend of infant mortality. Third, our scoping review concluded that in Brazil, regional inequalities can lead to contradictory results such as advanced maternal age as a protective factor for low birth weight. In some regions of the country maternal age conflicts with the level of maternal education. This creates a confounding factor in specific regions of the country. It is a phenomenon known as the "Low Birth Weight Paradox" (Silva et al. 2010)**.** Thus, we have not found, nor have we been successful in developing a proxy that could be used as a control for the internal dimension in the CMHC. Finally, in terms of external validity, our results should be interpreted with caution in relation to the specificities of an upper-middle-income country in the Latin American context that when it comes to applying our conclusions in other countries in development.

Recommendations and implications for public policies

With regard to the support offered by the findings of the current work to decision-makers for interventions aimed at reducing infant mortality rates in Brazil, we provide some recommendations.

1. Considering that one of the most ambitious objectives of the BFP is to interrupt the intergenerational cycle of poverty in Brazil, the investment in public policies aimed at improving the quality and performance of the educational system, emerges as an element capable of acting at the same time in various dimensions of the Brazilian context. In addition to allowing the most effective use of public services by the beneficiaries of social and health policies, higher levels of education also mean more qualified workers and higher wages.

2. More dynamic wage policies could also have a protective effect to reduce the risk of infant mortality. The current minimum wage policy in force in Brazil provides for annual readjustments, proposed by the President and sanctioned through a vote in the National Congress. This model has been used for many decades and aims only at restoring wage losses due to variations in inflation rates, without any incentive to competitiveness or the improvement of labor relations. Policies linking the minimum wage to sectoral productivity gains, in shorter intervals and according to key performance indicators, could have a triple effect: on productivity, employment and living conditions.

3. Investments in technology and infrastructure that promote digital inclusion would bring enormous benefits, both in terms of greater employability and in the individual's health management.

4. The quality and access to health services are bottlenecks identified in the current work as limiters for reducing child mortality. Interventions and investments in actions that could improve the quality of and access to health services, whether through new methodologies for training personnel or in the form of remuneration of services, could improve the performance of the health service system. Also, the resumption of the *Mais Médicos* (More Doctors) Program, which imported to Brazil doctors specialized in primary health care from other Latin American countries could reduce the shortage of health professionals in the most remote regions of the country.

5. The comprehensiveness of services is a more complex problem to be addressed, as it arises as a result of the decentralization of resources and services. Given the high number of existing municipalities in the country (5565), this factor would be subject to a political predisposition

towards a broad administrative reform that includes the reduction of health regions, together with a reduction in the number of municipalities and a reorganization of services.

There still exist political developments of the recent economic and political crisis in Brazil that impose major difficulties to public health managers regarding possible reforms and new proposals aimed at greater social protection and improvement in the population health. Furthermore, the emergence of the COVID-19 pandemic poses greater challenges for emerging countries such as Brazil, which establish new priorities which may hinder efforts towards reforms in the health system.

The avenues of research to be explored in the future

The social determinants of health are dynamic and require constant updating if one pretends to support decisions based on evidence.

1. Our literature review suggested that there are differences in access to comprehensive health services with marked differences between urban and rural areas. A study that takes into account these differentials and their possible effects on infant mortality rates in Brazil, remains quite relevant.

2. There is a growing interest of public health researchers in studying the mechanisms that lead to obesity among adolescents and children in Brazil (Barbosa et al. 2019). We believe that our methodological proposal could offer new insights on the influence on SDH impact on childhood and adolescent obesity.

3. The prospect of long periods of decline in economic activity and employment due to the ongoing Covid-19 pandemic, and its possible consequences for the health of populations, also opens up new avenues of research. The likely effect of gaps in terms of digital inclusion, along with other socioeconomic inequalities, appears to be emerging as a promising subject to be investigated, especially in low- and middle-income countries.

Our methodological proposal may provide support for numerous research projects regarding the population health and social determinants of health in countries presenting subregional disparities relatively homogenously distributed among subregions.

Chapter 6 Conclusion

The overarching goal of this thesis was to identify the determinants of infant mortality in Brazil after the implementation of FHS and BFP in order to raise plausible hypotheses for the slowdown, the regional disparities, and the anomaly in the trend of declines in the infant mortality rate in Brazil. To attain this objective, we conducted three research papers: 1. a scoping review that aimed at identifying and summarizing the determinants of infant mortality in Brazil under the influence of FHS and BFP, with a view of raising hypothesis for the recent changes in the infant mortality rates in Brazil and identifying gaps in terms of research concerning the determinants of infant mortality in the country, 2. a descriptive retrospective analysis according to the perspective of Public Health and health inequalities by adopting the conceptual framework proposed by the WHO's CSDH, using data from under-one-year old infant mortality rate and from possible determinants of infant mortality in Brazil according to the findings of our scoping review (article 1) and 3. a methodological proposal in order to overcome the challenges to developing a panel data model using aggregated data from the 26 Brazilian states and different subregions according to the CMHC, with a view of inferring possible associations between our independents variables and infant mortality rates in Brazil, aiming at reviewing the hypothesis raised in the scoping review about the recent changes in the country's infant mortality indicators.

The global results of these studies demonstrated that in the light of the CMHC and the SDH, regional disparities related to inequalities in factors such as income, education, employment, fertility rate, access, and quality of health services, account for inequalities in infant mortality rates, especially in the north and Northeast macro-regions of the country, which likely hamper further reductions of infant mortality. Those inequalities would explain both the slowdown in the reduction and the tendency of the infant mortality rates to remain at relatively high levels. Results also demonstrated that variations in those factors for reasons relating to the economic and political crisis, likely have interrupted the secular trend of declining infant mortality rates. In this regard, results suggest that a sharp reduction in employment rate observed between 2014 and 2015, among other factors, may have had a delayed impact on IMR in 2016. The results also identified an association between employment and different infant mortality indicators, with employment rate possibly impacting infant mortality up one-year, under-five mortality up two-years and neonatal mortality up three-years at least. Finally, the studies have shown that there is a household income threshold that acts as a protective factor against child mortality, below which the greater the

proportion of households below this income bracket, the greater the risk of an increase in child mortality.

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Appendix 1 Research equations and results

Plan of concepts

Research question :

What are the determinants of infant mortality in Brazil ?

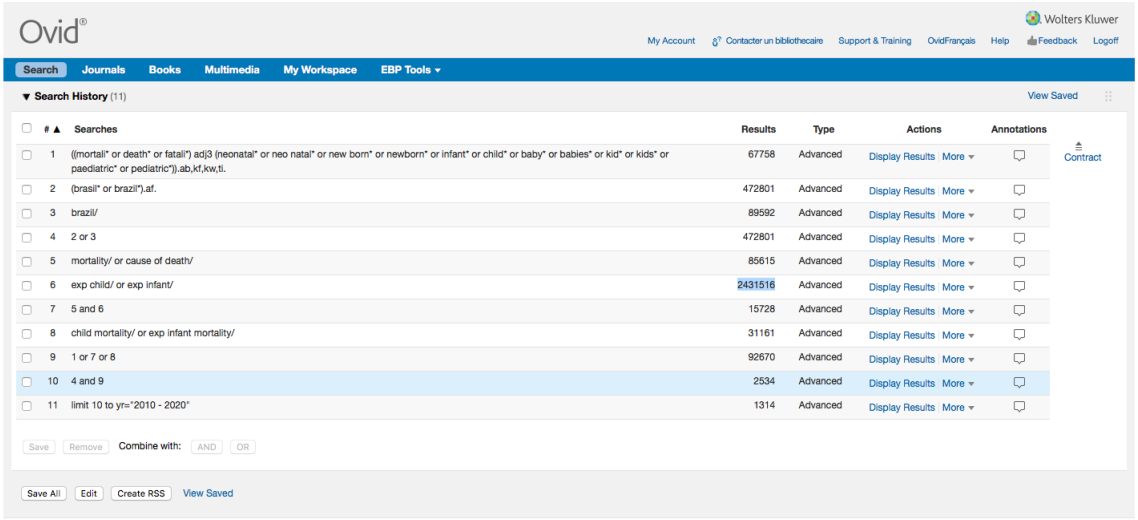
Concepts	Mortality	infant	Brazil
Key-words	Mortality Mortalities Morte Mortalidade Death* Death rate Death rates Fatality rates	Neonatal Infant Child Neonatal Neo natal Newborn New born Perinatal Baby Babies Kid Paediatric Pediatric	Brasil Brazil
Descriptors	Mortality (exp) Cause of death	Child Infant	Brazil
Descriptors	Child mortality Infant mortality		

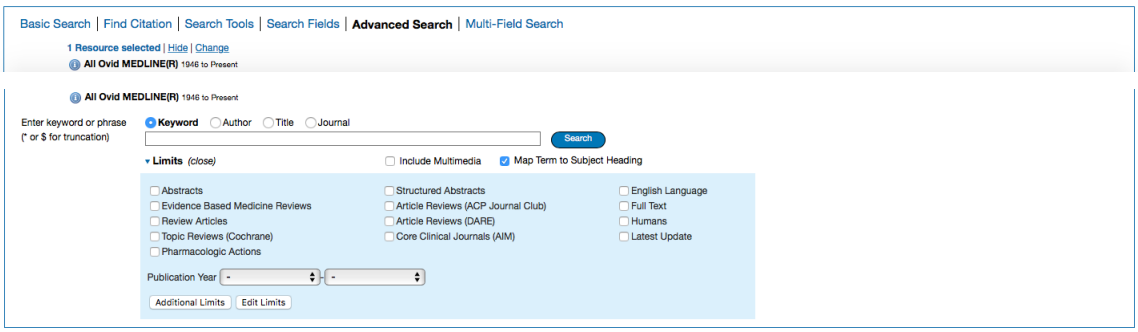
MEDLINE search equations (1314 references)

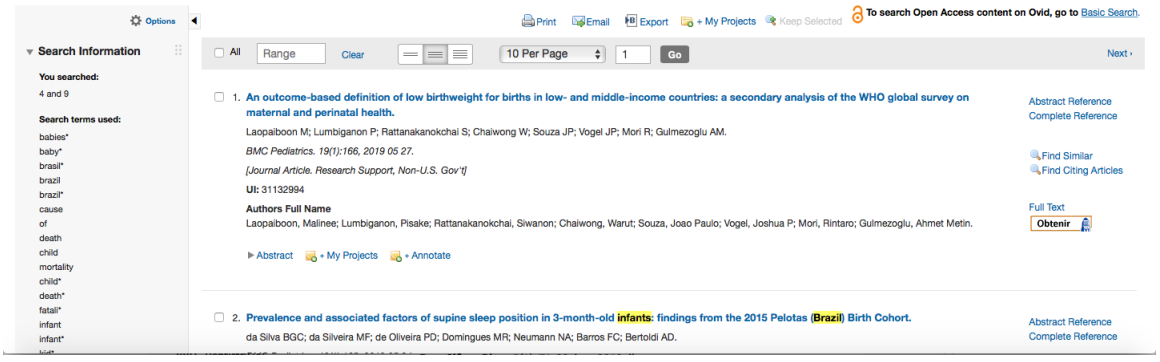
# Research	Equations	Results
1	((mortali* or death* or fatali*) adj3 (neonatal* or neo natal* or new born* or newborn* or infant* or child* or baby* or babies* or kid* or kids* or paediatric* or pediatric*)).ab,kf,kw,ti.	67.758
2	(brasil* OR brazil*).af.	472.801
3	Brazil/	89.592
4	3 OR 4	472.801
5	mortality/ OR cause of death/	85.615
6	Exp child/ OR exp infant/	2.431.516
7	5 AND 6	15.728
8	child mortality/ OR exp infant mortality/	31.161
9	1 OR 7 OR 8	92.670

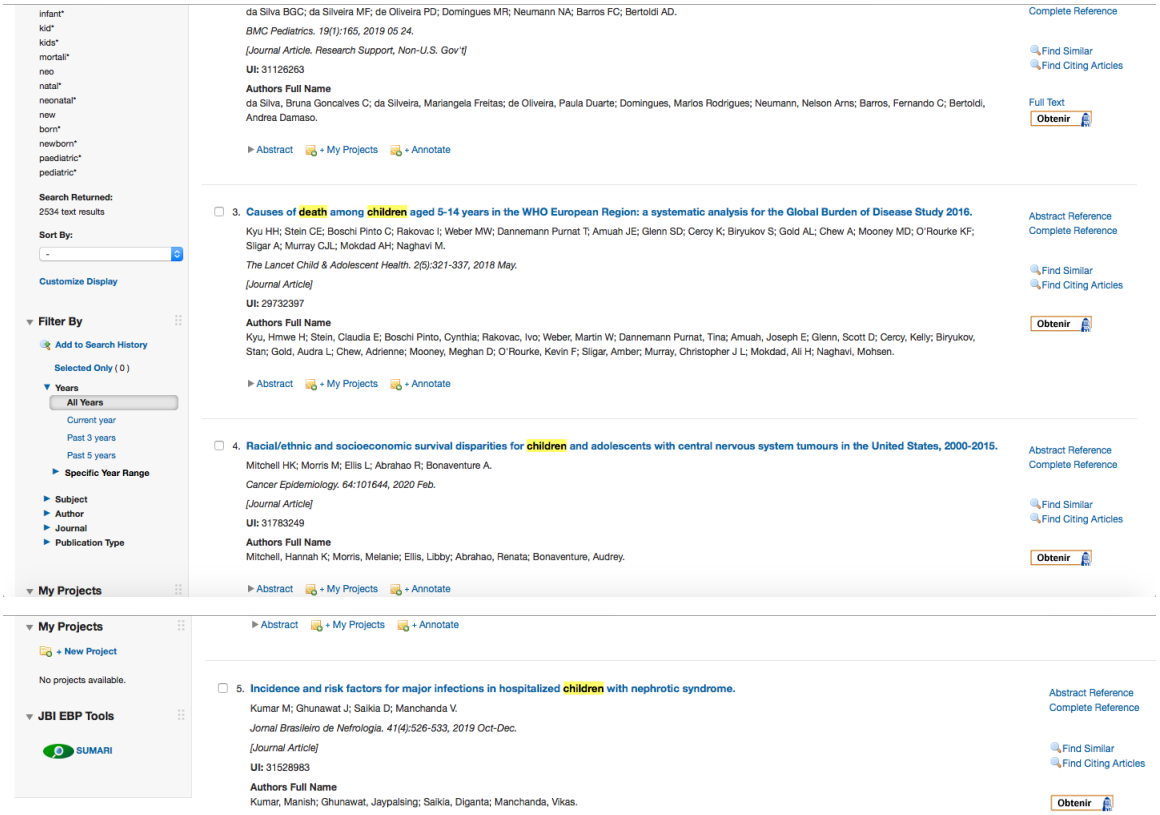
10	4 AND 9	2.534
11	limit 10 to yr=”2010- 2020	1.314

MEDLINE search print screen







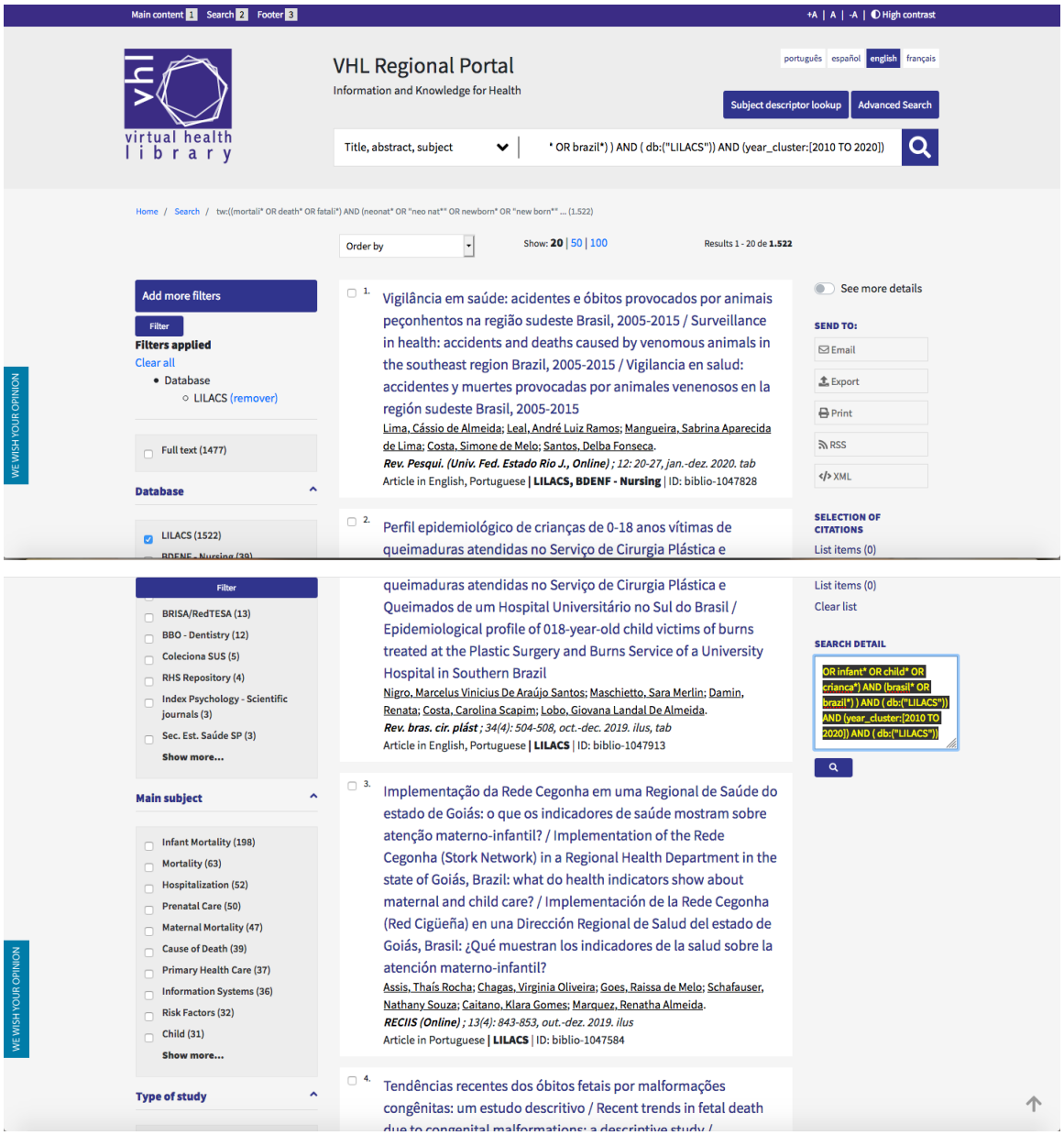


LILACS search equations (Concept 1 = 1.522 references ; concept 2 = 213 references ; total = 1.735)

Concepts	Concept 1	Concept 2
Key-words	Mortalidade Infantil no Brasil	Mortalidade Neonatal no Brasil
Descriptors **SCIELO database**	mortalidade, infantil, brasil	mortalidade, neonatal, brasil
Concept 1 (research equations according to key-words)	w:((mortali* OR death* OR fatali*) AND (neonat* OR "neo nat*" OR newborn* OR "new born*" OR "recem nascido*" OR infant* OR child* OR crianca*) AND (brasil* OR brazil*)) AND (db:("LILACS")) AND (year_cluster:[2010 TO 2020]) AND (db:("LILACS"))	
Concept 2 (research equations according to descriptors)	mh:(mh:(((((mortality OR death OR "cause of death") AND (child OR infant OR "infant, newborn")) OR ("child mortality" OR "infant mortality" OR "perinatal mortality")) AND (brazil))) AND (db:("LILACS")) AND (year_cluster:[2010 TO 2020]))	

LILACS search print screen

Concept 1



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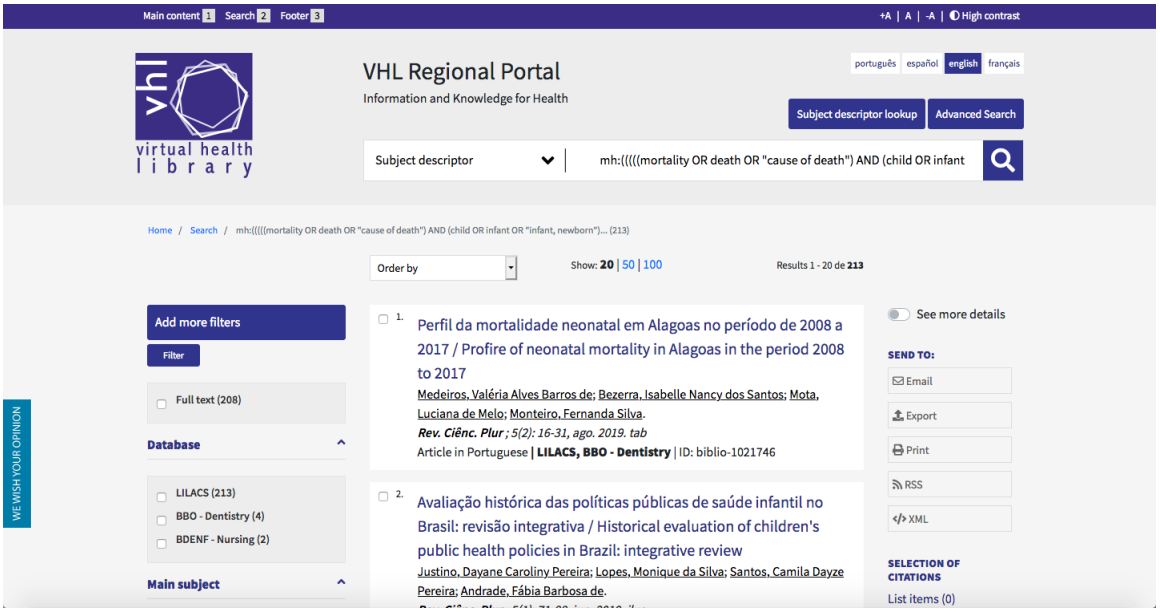
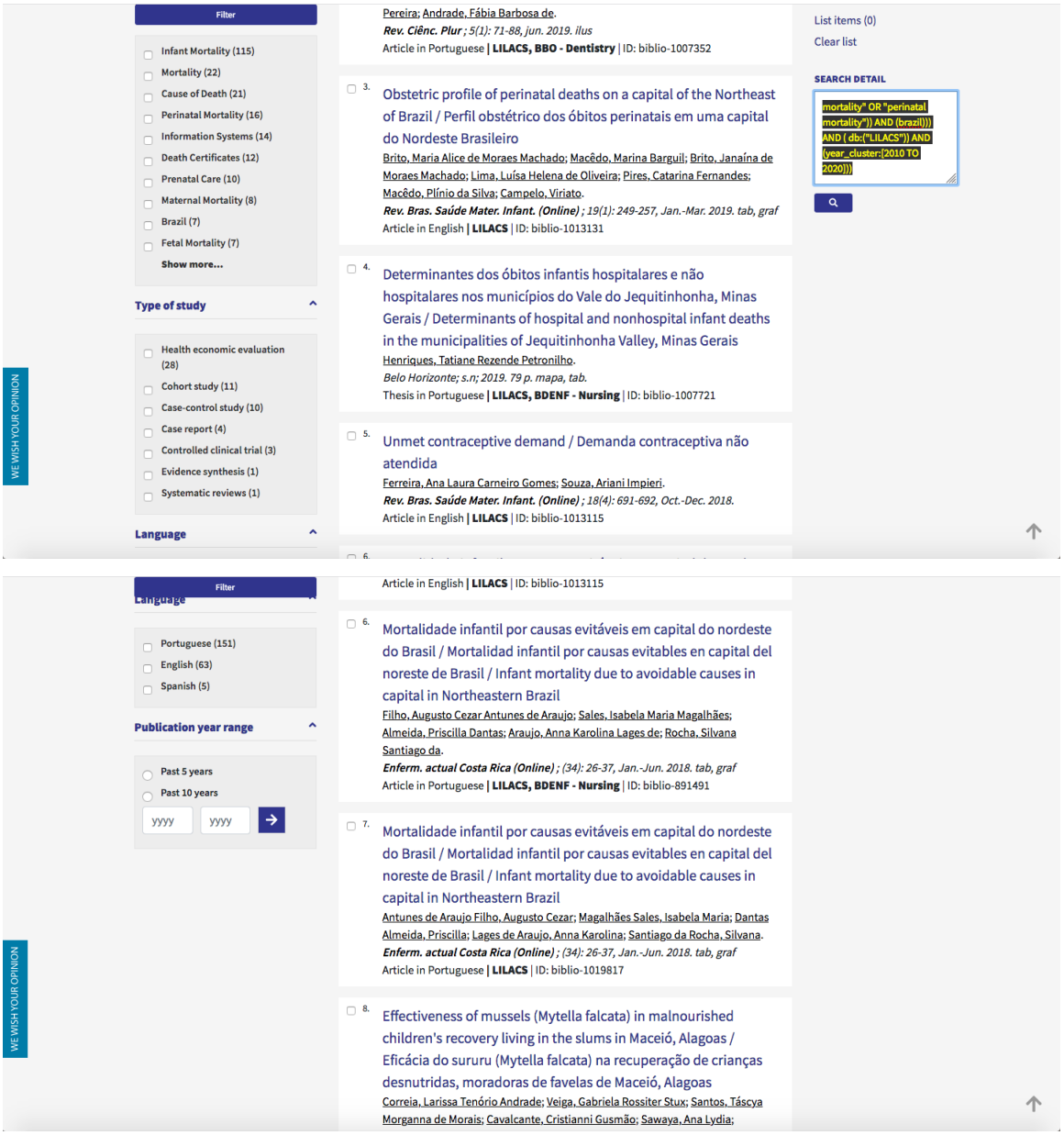
Concept 2

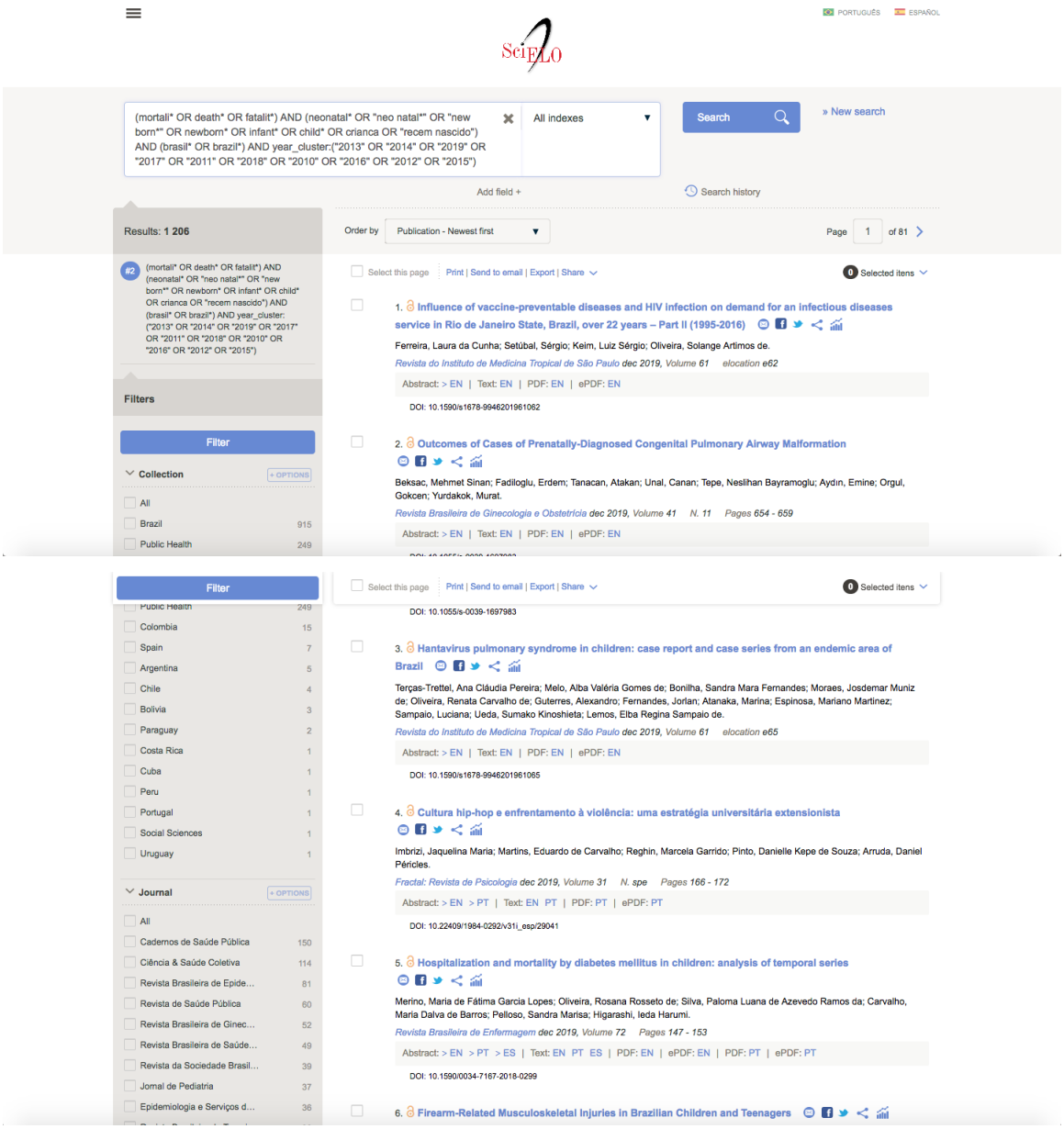


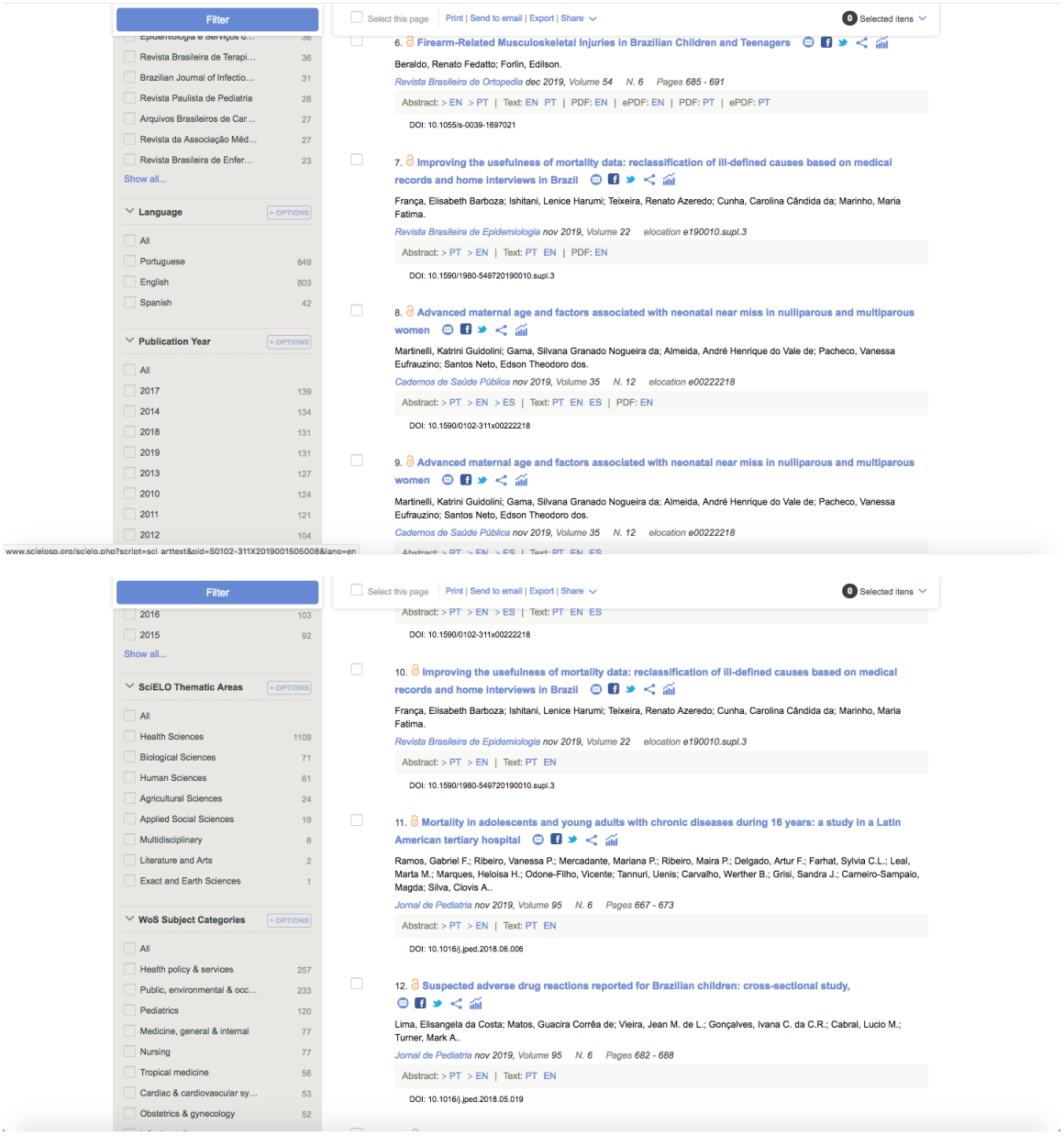


SCIELO search equations (1206 references)

Concept	
Research equations according to key-words	(mortali* OR death* OR fatalit*) AND (neonatal* OR "neo natal*" OR "new born*" OR newborn* OR infant* OR child* OR crianca OR "recem nascido") AND (brasil* OR brazil*) AND year_cluster:("2013" OR "2014" OR "2019" OR "2017" OR "2011" OR "2018" OR "2010" OR "2016" OR "2012" OR "2015")

SCieLO search print screen

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6. Firearm-Related Musculoskeletal Injuries in Brazilian Children and Teenagers
Beraldo, Renato Fedatto; Forlin, Edilson.
Revista Brasileira de Ortopedia dec 2019, Volume 54 N. 6 Pages 685 - 691
Abstract: > EN > PT | Text: EN PT | PDF: EN | ePDF: EN | PDF: PT | ePDF: PT
DOI: 10.1055/s-0039-1697021
7. Improving the usefulness of mortality data: reclassification of ill-defined causes based on medical records and home interviews in Brazil
França, Elisabeth Barboza; Ishitani, Lenice Harumi; Teixeira, Renato Azeredo; Cunha, Carolina Cândida da; Marinho, Maria Fatima.
Revista Brasileira de Epidemiologia nov 2019, Volume 22 elocation e190010.supl.3
Abstract: > PT > EN | Text: PT EN | PDF: EN
DOI: 10.1590/1980-549720190010.supl.3
8. Advanced maternal age and factors associated with neonatal near miss in nulliparous and multiparous women
Martinelli, Katrini Guidolini; Gama, Silvana Granado Nogueira da; Almeida, André Henrique do Vale de; Pacheco, Vanessa Eufrauzino; Santos Neto, Edson Theodoro dos.
Cadernos de Saúde Pública nov 2019, Volume 35 N. 12 elocation e00222218
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DOI: 10.1590/0102-311x00222218
9. Advanced maternal age and factors associated with neonatal near miss in nulliparous and multiparous women
Martinelli, Katrini Guidolini; Gama, Silvana Granado Nogueira da; Almeida, André Henrique do Vale de; Pacheco, Vanessa Eufrauzino; Santos Neto, Edson Theodoro dos.
Cadernos de Saúde Pública nov 2019, Volume 35 N. 12 elocation e00222218
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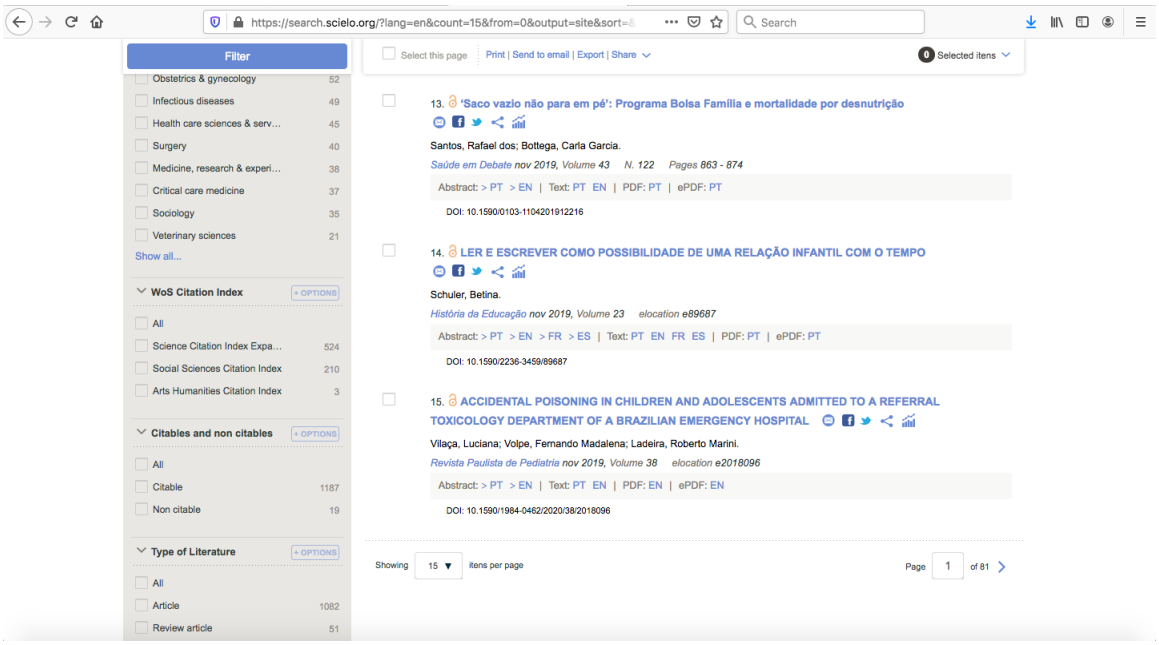
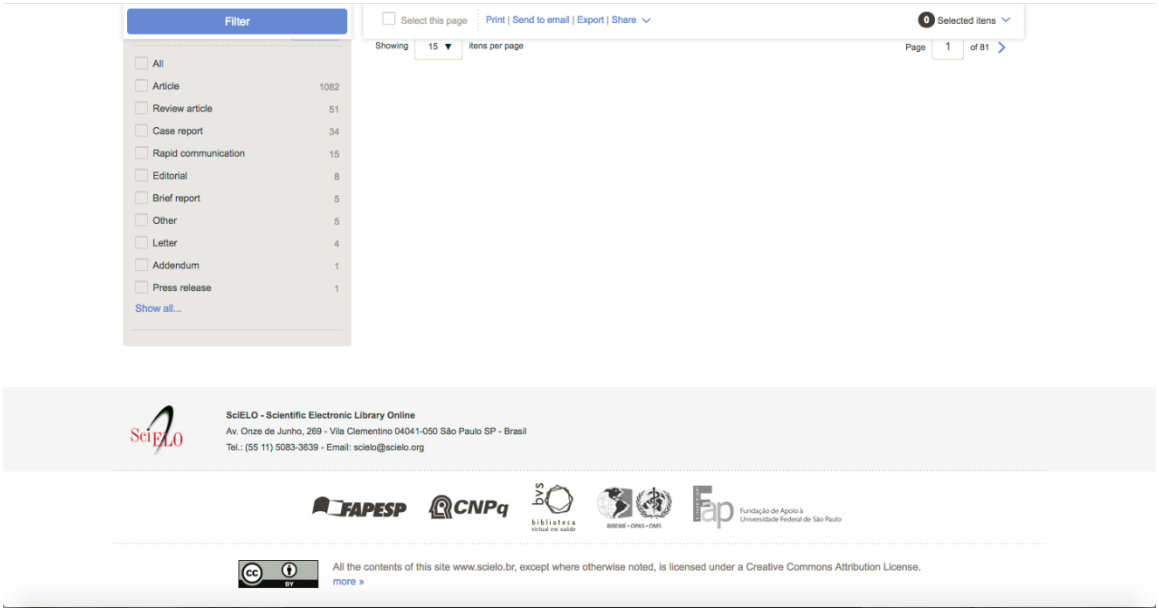
Abstract: > PT > EN > ES | Text: PT EN ES
DOI: 10.1590/0102-311x00222218
10. Improving the usefulness of mortality data: reclassification of ill-defined causes based on medical records and home interviews in Brazil
França, Elisabeth Barboza; Ishitani, Lenice Harumi; Teixeira, Renato Azeredo; Cunha, Carolina Cândida da; Marinho, Maria Fatima.
Revista Brasileira de Epidemiologia nov 2019, Volume 22 elocation e190010.supl.3
Abstract: > PT > EN | Text: PT EN
DOI: 10.1590/1980-549720190010.supl.3
11. Mortality in adolescents and young adults with chronic diseases during 16 years: a study in a Latin American tertiary hospital
Ramos, Gabriel F.; Ribeiro, Vanessa P.; Mercadante, Mariana P.; Ribeiro, Maira P.; Delgado, Artur F.; Farhat, Sylvia C.L.; Leal, Marta M.; Marques, Heloisa H.; Odone-Filho, Vicente; Tannuri, Uenis; Carvalho, Werther B.; Grisi, Sandra J.; Carneiro-Sampaio, Magda; Silva, Clovis A..
Jornal de Pediatria nov 2019, Volume 95 N. 6 Pages 667 - 673
Abstract: > PT > EN | Text: PT EN
DOI: 10.1016/j.jped.2018.06.006
12. Suspected adverse drug reactions reported for Brazilian children: cross-sectional study,
Lima, Elisangela da Costa; Matos, Guacira Corrêa de; Vieira, Jean M. de L.; Gonçalves, Ivana C. da C.R.; Cabral, Lucio M.; Turner, Mark A..
Jornal de Pediatria nov 2019, Volume 95 N. 6 Pages 682 - 688
Abstract: > PT > EN | Text: PT EN
DOI: 10.1016/j.jped.2018.05.019





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Appendix 2 Mixed Methods Appraisal Tool (MMAT) reading grid

INCLUS	NB. Utiliser le chiffre approprié pour cocher la bonne réponse s'il y a lieu dans l'une ou l'autre des cases en rose. Remplir un fichier par article					
DIMENSIONS SELON LE MODÈLE DE CAPACITÉS EN SANTÉ-MCS-RUGER	DIMENSION EXTERNE Environnement macro social, politique et physique (résultats des politiques macros)		DIMENSION EXTERNE Système de soins de santé, système d'éducation, effectif accès aux services	DIMENSION INTERMÉDIAIRE Normes, réseau social, vie communautaire (famille, école, religion, culture)	x	
Réviseur	AB			Note: Il y avait des preuves de grandes différences de distance géographique pour l'hospitalisation à la naissance, qui étaient associées au niveau socioéconomique, à la taille de la population et à l'emplacement de la municipalité de résidence, avec des effets significatifs sur les niveaux de mortalité infantile		
Numéro de l'article	REF (2)					
Nom du premier auteur et année	ALMEIDA, W.		2012			
Titre de l'article	Infant mortality and geographic access to childbirth in Brazilian municipalities					
A. PERTINENCE DE L'ARTICLE	Critères d'évaluation de la pertinence (Oui=1, Non ou ne sait pas=0)					
A. Questions sur la pertinence de l'article	Article répondant à l'ensemble des critères d'inclusion/exclusion			1		
	Article présentant un devis de recherche explicite			1		
DÉCISION (A)	Inclus =1 Exclus =0			1		
B. QUESTIONS PRELIMINAIRES	Réponses aux questions préliminaires (Oui=1, Non ou ne sait pas=0)					
B. Questions préliminaires	Y a-t-il une question de recherche qualitative ou quantitative claire (ou un objectif de reherche clair) ?			1		
	Les données collectées permettent-elles de répondre à la question de recherche (ou à l'objectif de recherche) ?			1		
DÉCISION (B)	Inclus=1 Exclus=0			1		
Objectif de l'étude	Analyser l'accès géographique à l'accouchement à l'hôpital au Brésil les municipalités					
Type d'étude	Choisir parmi les 6	C.4	Préciser le type de devis	Étude écologique avec analyse géospatiale		
C. QUALITE DES METHODES Préciser le type d'étude, en choisissant parmi les catégories ci-dessous	Critères d'évaluation de la qualité (Utiliser le chiffre 0, 1 ou 2 pour cocher la bonne réponse s'il y a lieu dans l'une ou l'autre des cases en rose. Chiffre 0 si réponse est NON ou impossible de répondre; chiffre 1 si réponse est oui en partie; chiffre 2 si réponse est clairement oui)					Score en %
C. 1. Études qualitatives	1.1. Les sources des données (p.ex., données d'entretiens individuels) permettent-elles de répondre à la question de recherche ?					
	1.2. Le processus d'analyse des données qualitatives permet-il de répondre à la question de recherche (p.ex, disponibilité des grilles d'analyse, du cahier de codification, etc) ?					
	1.3. Les auteurs ont-ils suffisamment pris en compte la manière dont les résultats sont liés au contexte (p.ex., le cadre dans lequel les données ont été collectées) ?					
	1.4. Les auteurs ont-ils suffisamment démontré la crédibilité des résultats présentés (p.ex., triangulation entre différentes sources de données, restitutions auprès des participants à la recherche, etc.) ?					
	1.5. Les auteurs ont-ils suffisamment pris en compte la manière dont leur présence influence les résultats (p. ex, leurs interactions avec les participants; réflexivité du chercheur) ?					
C. 2. Études quantitatives avec sélection aléatoire	2.1. Y a-t-il une description claire du processus de sélection aléatoire (randomisation) et/ou d'un processus de approprié de distribution dans les groupes ?					
	2.2. Y a-t-il une description claire du processus de sélection à l'aveugle ?					
	2.3. Les données sont-elles complètes (>80%) ?					
	2.4. Le nombre de perdus de vue est-il faible ? (<20%) ?					
C. 3. Études quantitatives sans sélection aléatoire	3.1. Le processus de sélection des participants permet-il de minimiser les facteurs de confusion ?					
	3.2. Les instruments de mesure de l'exposition (ou de l'intervention) et des effets sont-ils appropriés (origine claire, validité connue, outil validé, et absence de contamination entre les groupes si pertinent) ?					
	3.3. Dans les groupes comparés (exposés/non exposés; avec ou sans l'intervention; cas/contrôles), les participants sont-ils comparables, ou les chercheurs prennent-ils en compte (en les contrôlant) ces différences dans leurs analyses ?					
	3.4. Les données sont-elles complètes (>80%) et (si applicable) le taux de réponse est-il acceptable (>60%), ou y-a-t-il un taux acceptable de suivi pour les études de cohorte (selon la durée de suivi) ?					
C. 4. Études quantitatives descriptives	4.1. La stratégie d'échantillonnage permet-elle de répondre à la question de recherche ?			2		87.50
	4.2. L'échantillon est-il représentatif de la population à l'étude ?			1		
	4.3. Les instruments de mesure sont-ils appropriés (origine claire, validité connue, outil validé) ?			2		
	4.4. Le taux de réponse est-il acceptable(>60%)			2		
C. 5. Études mixtes	5.1. le devis de recherche mixte permet-il de répondre à la question de recherche ?					
	5.2. L'intégration des données qualitatives et quantitatives (ou des résultats) permet-elle de répondre à la question de recherche ?					
	5.3. Les auteurs ont-ils suffisamment pris en compte les limites associées au processus d'intégration (p.ex., divergence des données ou des résultats qualitatifs et quantitatifs dans le cas d'un devis de triangulation) ?					

C. 6. Recension systématique des écrits Oui =2 Oui partiellenent=1 Non, impossible de répondre=0	5.1. Les questions de recherche et les critères d'inclusion incluent-ils les composantes du PICO (Population, intervention, comparator, outcome)?		5.9. Les auteurs ont-ils utilisé une approche satisfaisante pour évaluer le risque de biais des études incluses?		
	5.2. Un plan de recherche pour la recension systématique était-il établi et y a-t-il une justification des écarts au protocole initial ?		5.10.Les auteurs rapportent-ils les sources de financement des études incluses ou ont-ils cherché cette information?		
	5.3. La sélection des devis de recherche inclus dans la recension est-elle justifiée?		5.11. Si métaanalyse ou autres formes de synthèse des preuves, les méthodes utilisées pour combiner les résultats des études individuelles sont-elles		
	5.4. La stratégie de recherche est-elle pertinente et exhaustive (p. ex., nombre et types de bases de données incluses pour la recherche, mots clés utilisés et leurs synonymes)?		5.12. Si métaanalyse ou autres formes de synthèse des preuves, les auteurs évaluent-ils le potentiel impact des risques de biais des études individuelles sur		
	5.5. La sélection des études a-t-elle été confiée à au moins deux personnes ?		5.13. Les auteurs prennent-il en compte les risques de biais des études individuelles dans l'interprétation et la discussion des résultats ?		
	5.6. L'extraction des données a-t-elle été confiée à au moins deux personnes ?		5.14. Les auteurs discutent-ils et fournissent-ils une explication satisfaisante de toute hétérogénéité observée dans les résultats des études incluses dans la recension ?		
	5.7. Une liste des études exclues est-elle fournie, avec justifciation des exclusions ?		5.15. La probabilité d'un biais de publication et son potentiel impact sont-ils évalués ?		
	5.8. Les caractéristiques des études incluses sont-elles indiquées avec suffisamment de détails ?		5.16. Les conflits d'intérêt sont-ils déclarés ?		
DÉCISION (C)	**Appréciation générale : Inclus=1 Exclus=0 (Exclusion si score inférieur à 80%**				1
D. POPULATION À L'ÉTUDE	**Critères d'évaluation de la représentativité de l'État/populations ou territoires (Oui=1, Non ou ne sait pas=0)**				
D. Les États/populations ou territoires ciblés sont représentatifs pour la question de recherche	**Description de l'États/populations/régions/ ou unités de services de soin: La totalité des 5564 municipalité du pays.**	1			1
DÉCISION FINALE (A+B+C+D)	**Appréciation générale : Inclus=1 Exclus=0 (seuil d'exclusion : 1 décision ou plus avec une réponse=0)**				1
Type de mortalité infantile	a) Mortalité néonatale précoce (0 à 7 jours)				
	b) Mortalité néonatale tardive (7 à 27 jours)				
	c) Mortalité néonatale (0 à 27 jours)				
	d) Mortalité postnéonatale (27 à 364 jours)				
	e) Mortalité infantile de 0 à 1 an	X			
	f) Mortalité infantile de 0 à 5 ans				
Variables independantes	Région: Nord, Nord-est, Sud-est, Sud et Centre-ouest				
	Population: 1 à 20.000; 20.000 à 50.000; 50.000 à 200.000 et 200.000 ou plus d'habitants				
	Revenu par habitant				
	Lits de soins intensifs néonatals par 1000 naissances vivant				
	Proportion de naissances vivant à domicile				
	Distance parcourue jusqu'à la livraison				
Échantillon	Les nouveau-nés et les infants décédés dans les 5564 municipalités du pays.				
Période d'observation	2005-2007				
Résultats					
Conclusions	Il y avait des preuves de grandes différences de distance géographique pour l'hospitalisation à la naissance, qui étaient associées au niveau socio-économique, à la taille de la population et à l'emplacement de la municipalité de résidence, avec des effets significatifs sur les niveaux de mortalité infantile. Dans le contexte de la régionalisation des soins de santé et de la logique de planification intégrée, les résultats suggèrent que les disparités d'accès géographique à l'accouchement à l'hôpital restent un défi à surmonter dans la structure des systèmes de santé régionaux.				
Discussion	Plus la distance géographique pour l'hospitalisation à l'accouchement est grande, plus l'IMR est élevé, même en contrôlant les effets de la région, de la taille de la population, du revenu municipal et de l'accès. Au Brésil, les services de santé sont concentrés dans les zones urbaines, les capitales et les zones centrales, au détriment des zones rurales, des zones les plus pauvres et de la périphérie. Il en résulte une grande disparité de l'offre et plus de difficultés d'accès aux services de santé, ainsi que des facteurs socio-économiques et culturels.				
Références pertinentes	3. Campos TP, Carvalho MS. Assistência ao parto no Município do Rio de Janeiro: Perfil das maternidades e o acesso da clientela. Cad Saude Publica. 2000;16(2):411- 20. DOI:10.1590/S0102-311X2000000200011				
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	10. Leal MD, Gama SG, Cunha CB. Desigualdades raciais, sociodemográficas, e na assistência ao pré-natal e ao parto, 1999-2001. Rev Saude Publica. 2005;39(1):100- 7. DOI:10.1590/S0034-89102005000100013				
Commentaires de chaque réviseur dans des cases différentes (ex. la contribution et la pertinence de l'article par rapport aux objectifs de recherche)	Discussion II: Bien qu'elles aient été élaborées au cours de la dernière décennie, d'importantes stratégies visant à améliorer la qualité et l'accès aux soins pour les femmes enceintes semblent insuffisantes pour garantir l'égalité d'accès aux services d'accouchement. La distance intercommunale plus longue était un facteur de risque de mortalité infantile et est liée aux disparités de l'offre des services de qualité et le manque de communication entre les soins ambulatoires et l'assistance à l'accouchement. Malgré sa caractéristique universelle, le SUS nécessite des mécanismes efficaces qui garantissent l'accessibilité à la population des municipalités de plus petite taille avec un niveau socio-économique plus défavorable.				
Revue	Revista de Saúde Pública				
Lien URL/DOI	http://dx.doi.org/10.1590/S0034-89102012005000003				

Appendix 3 Correlation Matrix

. corr nmr imr u5mr occ occ1 occ2 occ3 rgdp isa isb isc isd ise isf bfp fr edat lbpre meden wct swt
(obs=312)

	nmr	imr	u5mr	occ	occ1	occ2	occ3	rgdp	isa	isb	isc	isd	ise	isf	bfp	fr	edat	lbpre	meden	wct	swt
nmr	1.0000																				
imr	0.8903	1.0000																			
u5mr	0.7700	0.8847	1.0000																		
occ	−0.3449	−0.3258	−0.2200	1.0000																	
occ1	−0.4174	−0.4165	−0.3353	0.7303	1.0000																
occ2	−0.4192	−0.3864	−0.3198	0.6853	0.7583	1.0000															
occ3	−0.4285	−0.3905	−0.3115	0.6162	0.7299	0.7635	1.0000														
rgdp	−0.6563	−0.6682	−0.6698	0.1693	0.2650	0.2265	0.1904	1.0000													
isa	−0.2225	−0.1635	−0.1833	0.1035	−0.0184	−0.0387	−0.0599	0.2985	1.0000												
isb	−0.3670	−0.3500	−0.3651	0.1849	0.1149	0.0689	0.0313	0.5152	0.8288	1.0000											
isc	−0.4659	−0.4738	−0.4706	0.3089	0.2555	0.2002	0.1461	0.6487	0.6989	0.9305	1.0000										
isd	−0.4793	−0.5260	−0.4881	0.3536	0.3099	0.2536	0.1893	0.7033	0.5066	0.7691	0.8814	1.0000									
ise	0.4454	0.4333	0.4468	−0.2861	−0.2194	−0.1452	−0.1146	−0.6386	−0.7299	−0.9075	−0.9386	−0.8075	1.0000								
isf	0.4596	0.4672	0.4369	−0.2622	−0.1910	−0.1387	−0.0734	−0.6941	−0.6337	−0.8662	−0.9324	−0.9456	0.8525	1.0000							
bfp	−0.4748	−0.5640	−0.5069	0.1734	0.3091	0.3102	0.3271	0.3806	−0.4367	−0.2812	−0.1476	−0.0041	0.1804	0.1003	1.0000						
fr	0.5719	0.7364	0.7530	−0.1859	−0.2724	−0.2640	−0.2685	−0.5998	−0.2361	−0.3041	−0.3804	−0.4044	0.3877	0.3380	−0.4390	1.0000					
edat	−0.5987	−0.6475	−0.6301	0.2119	0.2612	0.2446	0.2102	0.6335	0.2744	0.5423	0.6163	0.6143	−0.5519	−0.6061	0.3752	−0.4521	1.0000				
lbpre	−0.2189	−0.1843	−0.2170	−0.1076	−0.1319	−0.1656	−0.1520	0.4030	0.6215	0.6029	0.5281	0.4306	−0.5600	−0.5334	−0.3116	−0.1976	0.2889	1.0000			
meden	−0.4289	−0.4932	−0.5116	0.0108	0.0480	0.0071	−0.0135	0.6326	0.4693	0.5834	0.5743	0.5688	−0.5821	−0.5859	0.0457	−0.4846	0.4269	0.5097	1.0000		
wct	−0.1629	−0.2443	−0.3150	−0.1984	−0.1541	−0.1184	−0.0976	0.0969	0.0681	0.0135	−0.0492	−0.1509	−0.0016	0.1554	0.2772	−0.3890	0.2100	0.0382	0.2911	1.0000	
swt	−0.3890	−0.4116	−0.4960	−0.1732	−0.1348	−0.1433	−0.1548	0.5290	0.3958	0.3431	0.3053	0.2598	−0.3971	−0.2963	0.1335	−0.5700	0.3934	0.4112	0.4722	0.3663	1.0000

Appendix 4 Estimation for fixed effect clustering by “macro-regions” and “year” and absorbing “year”

```
 reghdfe imr occ1 rgdp bfp fr edat lbpre wct swt, absorb(year) vce(cluster mr_year)
(MWFE estimator converged in 1 iterations)

HDFE Linear regression                            Number of obs   =        312
Absorbing 1 HDFE group                            F(   8,     59) =      68.74
Statistics robust to heteroskedasticity           Prob > F        =     0.0000
                                                  R-squared       =     0.7523
                                                  Adj R-squared   =     0.7362
                                                  Within R-sq.    =     0.6315
Number of clusters (mr_year) =         60         Root MSE        =     1.5521

                                (Std. Err. adjusted for 60 clusters in mr_year)
------------------------------------------------------------------------------
             |               Robust
         imr |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        occ1 |  -18.07709   5.532892    -3.27   0.002    -29.14838   -7.005798
        rgdp |  -.0678394   .0274506    -2.47   0.016    -.1227679   -.0129109
         bfp |  -5.042564   1.309268    -3.85   0.000    -7.662404   -2.422725
          fr |   3.177065   .4692721     6.77   0.000     2.238054    4.116076
        edat |  -.0711601   .0153569    -4.63   0.000    -.1018892   -.0404311
       lbpre |  -1.343528    .749344    -1.79   0.078    -2.842962    .1559063
         wct |   .6016051   .4973179     1.21   0.231    -.3935259    1.596736
         swt |   .3306142   .3857537     0.86   0.395    -.4412771    1.102506
       _cons |   32.75663   4.874279     6.72   0.000     23.00322    42.51004
------------------------------------------------------------------------------
```