The relation between the health workforce distribution and maternal and child health inequalities

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The Relation Between the Health Workforce distribution and Maternal and Child Health Inequalities

De relatie tussen de spreiding van gezondheidszorgaanbieders en ongelijkheid in moeder- en kindersterfte

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Publications and working papers

Chapters 2 to 8 are based on the following articles:

1. Sousa A, Scheffler R, Nyoni J, Boerma T, **A comprehensive health labour market framework for universal health coverage**. Bulletin of the World Health Organization, 2013. 91: p. 892-894.
2. Sousa A, Dal Poz M, Carvalho CL, **Monitoring inequalities in the health workforce: the case study of Brazil 1991-2005**. PLoS ONE, 2012. 7(3): p. e33399.
3. Sousa A, Lozano R, Gakidou E, **Exploring the determinants of unsafe abortion: improving the evidence base in Mexico**. Health Policy Plan, 2010. 25(4): p. 300-310.
4. Sousa A, Canning D, Dal Poz MR, Evans BD, **Primary health care provision of maternal health services in Brazil**. 2011.
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6. Sousa A, Dal Poz M, Boschi-Pinto C, **Reducing inequities in neonatal mortality through adequate supply of health workers: evidence from newborn health in Brazil**. PLoS ONE, 2013. 8(9): p. e74772.
7. Sousa A, Van de Poel E, Nigenda G, Van Doorslaer E, **Explaining the inequalities in infant mortality in Mexico: A decomposition analysis**. 2015.

Chapter 1

General introduction

Weak health systems with a shortage of qualified staff, and lack of equipment and medicines impede the delivery of quality health care that is required to prevent maternal and newborn deaths and the attainment of the health-related Millennium Development Goals (MDGs) [1, 2]. Countries with a higher number of health workers per inhabitant have higher levels of health in the population, and better levels of intervention coverage, after controlling for other possible determinants [3-9].

The majority of maternal and child deaths occur in low-resource settings, and could be prevented by improving access to effective maternal and child health interventions among poor people [10]. In many low- and middle-income countries, the poorest 20% of the population are less likely to be covered by maternal and child health interventions than their wealthier counterparts [11]. This is a particular challenge if countries want to attain Universal Health Coverage[1].

Using the cases of Mexico and Brazil, this thesis investigates whether some of the health sector policies and interventions have been successful in reducing maternal and child health inequalities and improving the health of poor people. These countries were chosen because they have large maternal and child health inequalities [13-24], and since these inequalities were perceived as being inequitable[2], both countries implemented several policies to decrease them [25-29]. They are also the largest two countries in Latin America, accounting for more than half of the total population of the region [30].

The Latin America region is one of the regions with the greatest progress towards the reduction of child mortality. It has reduced the under-five mortality rate by more than half from 54 deaths per 1,000 live births in 1990 to 18 deaths per 1,000 live births in 2013 (see Figure 1). However, the proportion of under-five and infant mortality attributed to neonatal mortality (deaths between 0-27 days) has increased in the past ten years. Most of the neonatal deaths occur during the early neonatal period and could be averted with access to a functioning health facility or to qualified health workers during and after pregnancy and child birth [31, 32].

Country estimates in Mexico and Brazil also show major progress in reducing under-five mortality (see Figure 1). Between 1990 and 2013 child mortality in Brazil dropped from 62 deaths per 1,000 live births to 14 deaths per 1,000 live births. In Mexico the rate dropped from 46 deaths per 1,000 live births to 15 deaths per 1,000 live births, a decline of more than one third during the period. This implies that both countries have already attained the fourth MDG target to reduce the under-five mortality rate.

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[1] Defined as access of all people to comprehensive health services including prevention, promotion, treatment, and rehabilitation at affordable cost and without financial hardship, through protection against catastrophic health expenditures [12].

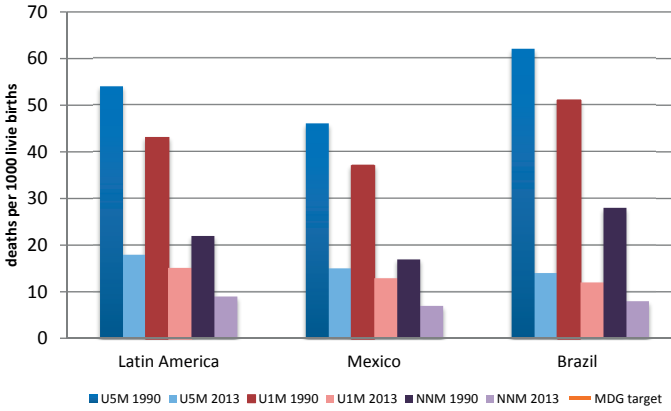
[2] Health inequities are defined as the unfair and avoidable differences in health status seen within and between countries [38].

However, in both countries the proportion of under-five deaths attributed to neonatal mortality accounts for more than half of their under-five and infant deaths making it one the biggest health challenges the countries now face. Brazil is also among the top ten countries with the highest number of preterm births [33].

In spite of major progress in previous decades to reduce child mortality, major health inequalities exist in both countries. The poorest areas in Brazil and Mexico have higher rates of child and maternal mortality than their wealthier counterparts [13-24].

In addition, neither of the two countries is likely to attain the MDG 5 to reduce the maternal mortality rate by 75% between 1990 and 2015. In Brazil between 1990 and 2013 maternal mortality declined by 43% from 120 to 69 deaths per 100,000 live births. In Mexico, it declined by 45% from 88 to 49 deaths per 100,000 live births [34].

Figure 1 Child, infant and neonatal mortality rates per 1000 live births in Latin America, Mexico and Brazil 1990-2013



Source: UNICEF 2014 [32]

I. Socioeconomic context

Mexico and Brazil are classified as upper middle-income countries and are considered to be among the most important emerging economies of the world [35]. However, despite their economic achievements, both countries struggle with poverty and have large income inequalities (see Table 1). In 2013, Brazil had a Gini index[3] of 53 and Mexico a Gini of 47. In Brazil, the poorest 20% earn 3.3% of the income while the richest 20% earn 57.6% and in Mexico the poorest 20% earn 4.9% of the income while the richest 20% earn 52.8%. In 2012, 24% of the population in Mexico and Brazil lived

[3] A Gini coefficient of zero expresses perfect equality while, a Gini coefficient of 100 expresses maximal inequality.

below four dollars a day. However, Mexico ranks higher in the human development index as a result of better life expectancy, higher average years of education and greater income per capita.

Table 1 Socioeconomic data for Mexico and Brazil

	Year	Mexico	Brazil
GNI per capita (2011 PPP $) (b)	2013	$15,854	$14,275
GDP growth (annual %) (a)	2013	1.1	2.5
Total population (millions) (a)	2013	122.3	200.4
Poverty headcount ratio at $4 a day (PPP) (% of population) (a)	2012	23.7	23.8
GINI (a)	2011	47.2 (2010)	53.1
HDI rank (b)	2013	71	79
Life expectancy at birth (b)	2013	77.5	73.9
Mean years of schooling (b)	2012	8.5	7.2

Source: (a) WD indicators 2014, (b) HDI Report 2014 [30, 36]

II. Health care policies and reforms

The Mexican and Brazilian governments have implemented several public health and inter-sectoral interventions to reduce maternal and child mortality among the poor. In Mexico, the main policies implemented include the conditional cash transfer program 'Oportunidades' implemented in 1997 to improve health, education and nutrition of poor families with children [25] and 'Equal Start in Life' or 'Arranque Parejo de vida' implemented in 2001 to reduce maternal and perinatal deaths in deprived areas [26]. In Brazil the policies include, 'Family Health Programme' implemented in 1994 to provide and improve primary health care, particularly maternal and child care, among poor people [27], 'Zero Hunger Programme' or 'Fome Zero' implemented in 2003 to guarantee access to basic food to the poorest families [28], and 'Cash Transfer Programme' or 'Bolsa Familia' implemented in 2003 to improve the health, education and nutrition of poor families with children [29]. Other public health and inter-sectoral programs have also been introduced in both countries to reduce maternal and child deaths, such as access to clean water and sanitation, education of mothers and immunization coverage. Indeed the literature shows that both social determinant interventions and health systems interventions have an impact on access to health care [2,38].

Over the last two decades both countries have undertaken a series of major health reforms to provide universal access to health services. In Brazil the 'Unified Health System' or 'Sistema Unico de Saude - SUS' was implemented in 1991 to provide universal access to health services free of charge to the entire population. It was combined with large-scale decentralization of decision-making to the municipality governments (one

level below the state) [27]. In Mexico the 'Popular Health Insurance' or 'Seguro Popular' was implemented in 2003. It provided universal access to health services and targeted poor families that had been previously excluded from health insurance [37].

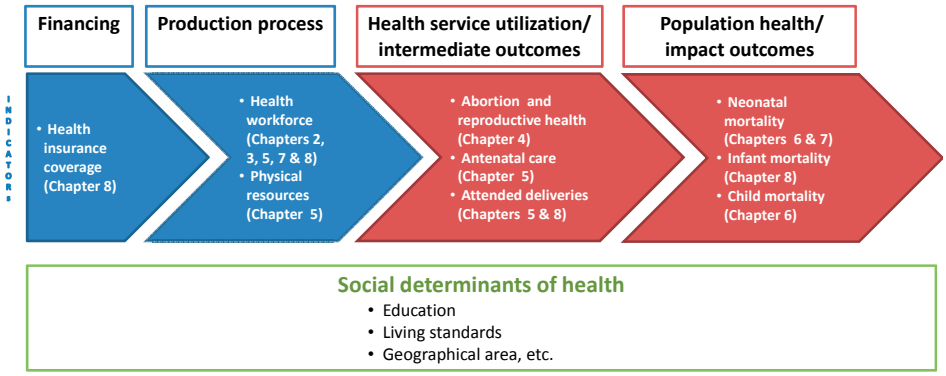
However, despite the efforts made by the Brazilian and Mexican governments to increase poor peoples' access to maternal and child health services there is surprisingly little evidence of the effect these policies had in reducing inequalities at sub-national level. Indeed, one of the major challenges for both countries remains the reduction of maternal and child health inequalities at subnational level.

III. Framework and structure of the thesis

To understand if the health care interventions have improved maternal and child health inequalities, this thesis contains seven research papers which are the main topics forming the backbone of health systems. The backbone is composed of four key elements: financing, production process, health service utilization and population health, which are interwoven to form a flow of key indicators for which data are available. This flow is depicted in Figure 2 pointing to the chapters of the thesis that include the outlined indicators.

The availability of financial, human and physical resources for the entire population is one of the determinants of inequalities in access to health care services and of the population's health. Three key population health indicators are investigated: neonatal mortality, infant mortality and child mortality; and three key health service utilization indicators are investigated: unsafe abortion, coverage of antenatal care and attended deliveries in health facilities. In the Commission on Social Determinants of Health (CSDH) framework, the social determinants of health are also assumed to co-determine inequalities in access to health care [38]. They are assumed to influence each element of

Figure 2 Framework



the health system from the financing to population health outcomes. For this reason the key social determinants of community and household-level characteristics are included in all analyses.

The chapters in this thesis have adopted a variety of methods to measure inequalities in maternal and child healthcare at a subnational level across socioeconomic groups over a period where major health reforms were undertaken in Mexico and Brazil.

Production process

The first issue covered in this thesis involved the production process of health care. As demonstrated by the latest ebola outbreak, health workers are a fundamental and instrumental component of health service delivery. Unless countries have the appropriate health workforce to identify outbreaks and deliver quality services, equitable access to health services and universal health coverage will not be attained. This is particularly challenging for many low- and middle-income countries, which often suffer from severe shortages and uneven distribution of health workers, which limits access to health services for certain groups of the population. Evidence of the effects of health worker distribution on the delivery of health services and the health of the population at subnational level is still scant.

The first study of this thesis (chapter two), 'A comprehensive health labour market framework for universal health coverage' [39], proposes a framework to develop effective health workforce policies through a health labour market approach. This is particularly important as many low- and middle-income countries often develop health workforce policies ignoring the dynamics of the health labour markets. The research question addressed in this paper is: which health workforce policies have the potential to increase access to health care services?

The study in chapter three, 'Monitoring inequalities in the health workforce: the case study of Brazil 1991-2005' [40] elucidates the large health workforce inequalities in Brazil by investigating inequality trends in the distribution of the health workforce at sub-national level and identifying the sources of the inequalities using the Gini and Theil index. The research question addressed in this paper is: are there inequalities in the distribution of health workers in Brazil and have these inequality gaps decreased over time?

Health service utilization/ intermediate outcomes

Two studies were undertaken to examine inequalities in utilization of maternal and child health services. The first health service utilization indicator investigated in this thesis is unsafe abortion. Unsafe abortion is defined as a 'procedure for terminating an

unintended/unwanted pregnancy either by individuals without the necessary skills or in an environment that does not conform to minimum medical standards, or both' and is based on the WHO definition [41]. Worldwide, unsafe abortion and its complications are one of the main causes of maternal mortality and morbidity [34]. In Mexico, abortion is considered as one of the main causes of maternal mortality [42]. The study in chapter four, 'Exploring the determinants of unsafe abortion: improving the evidence base in Mexico' [43] uses the first population survey conducted in Mexico that included questions on abortion as part of the pregnancy calendar, to explore the relationship between unsafe abortion and various socioeconomic and demographic characteristics. The research question addressed in this paper is: what are the determinants of unsafe abortion in Mexico?

Most maternal and newborn deaths are directly related to inadequate care during and after pregnancy and childbirth [32, 34]. The study in chapter five, 'Primary health care provision of maternal health services in Brazil' [44] further explores the findings of chapter three on access to maternal and child health. The associations between the provision of health workers, health infrastructure, public private mix, and the utilization of antenatal care and attended deliveries in health facilities in the poor and rich municipalities are investigated using a seemingly unrelated Tobit regression model with corner solution application. The research questions addressed in this paper are: are there inequalities in the utilization of maternal and child health services in Brazil?; and are inequalities in the availability of health resources associated with the use of maternal and child health services?

Population health/impact outcomes

In this section three studies were undertaken to measure inequalities in neonatal, infant and child mortality and to explore whether increases in the utilization of health care services have led to improved health outcomes.

Worldwide, neonatal mortality represents 59% of infant mortality. In Brazil, neonatal mortality is 67% of infant mortality [32]. However, there is no accurate data to monitor its progress at sub-national level. The study in chapter six, 'Sub-national assessment of inequality trends in neonatal and child mortality in Brazil' [45] new data on neonatal mortality at subnational level are produced and used to measure inequality trends in neonatal and child mortality in Brazil. The research question addressed in this paper is: are there inequality gaps in neonatal and child mortality in Brazil and have these inequality gaps decreased over time?

In chapters five and seven, different data and methods are examined to explain the differences in the supply of health workers and neonatal mortality across socioeconomic groups. These findings are further explored in chapter seven, 'Reducing inequities in

neonatal mortality through adequate supply of health workers: evidence from newborn health in Brazil' [46]. This study explores the relationship between the supply of health workers and neonatal mortality in poor and non-poor areas in Brazil using a fixed effects regression model. Particular emphasis is given to neonatal mortality as most of the neonatal deaths could be averted with a well-functioning health system. The research question addressed in this paper is: are the differences in the supply of health workers and skill-mix composition associated with inequalities in neonatal mortality?

In the final study the analysis of inequalities is expanded to measure inequalities in infant mortality across the entire socioeconomic distribution and to identify the determinants of these inequalities and their changes over time. The study in chapter eight, 'Explaining the inequalities in infant mortality in Mexico: a decomposition analysis' [47] uses data for the municipalities in 2000 and 2005 to investigate the determinants of the infant mortality gap in Mexico using the corrected concentration index decomposition method. The research questions addressed in this paper are: have socio-economic inequalities in infant mortality changed across the years?; what are the determinants of infant mortality in Mexico at municipality level?; and which factors have contributed to the changes in socio-economic inequalities in infant mortality?

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Part I

Production process

Chapter 2

A comprehensive health labour market framework for universal health coverage

Sousa A, Scheffler RM, Nyoni J, Boerma T.

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Introduction

In many developed and developing countries, progress towards attaining UHC is hindered by the lack of a health workforce large enough and with the proper skills to deliver quality services to the entire population. Several factors accentuate the problems associated with health worker shortages, especially in low- and middle-income countries: maldistribution and migration of the workforce, inappropriate training, poor supervision, unregulated dual practice, imbalances in skill-mix composition, and reduced productivity and performance.[1] Such problems are, however, not limited to low- and middle-income countries; many high-income countries are likely to face severe shortages of health workers because of budget cuts for social services resulting from the global economic downturn. The ageing of the population puts further pressure on health systems by increasing the demand for health care. Moreover, the changing dynamics of workforce migration, such as the increased exodus of workers from one developing country to another, pose a challenge for global health labour markets.[2]

Comprehensive health workforce policies

To address the challenges described and attain UHC, countries will have to develop effective policies to optimize the supply of health workers. This can only be accomplished through comprehensive planning of the health workforce based on an in-depth analysis of the health labour market to understand the driving forces affecting workforce supply and demand, both within countries and at the global level.

Partial health workforce policies designed on the basis of needs-based estimates and focused on training more health workers are not sufficient in addressing health worker shortages. The needs-based approach consists of estimating the number of health workers required to meet the needs of the population. Although these estimates are useful to inform the demand of health workers, they are not enough to formulate effective health workforce policies because they ignore the dynamics of the health labour market.[3] Workforce shortages cannot be resolved by simply training more health workers; the health labour market conditions also have to be such that the newly-trained health workers can be absorbed into the health workforce. Otherwise, a fraction of them will migrate, work in another sector or remain unemployed and the resources spent on training them will have gone to waste.[4]

Health labour market dynamics are the main determinant of the level of employment in a country – not the health needs of the population or the education sector alone. The health labour market is influenced by the health needs of the population, the demand for health services and the supply and governance of health workers. Together these factors determine workers' wages and allowances, the number of health workers employed, the

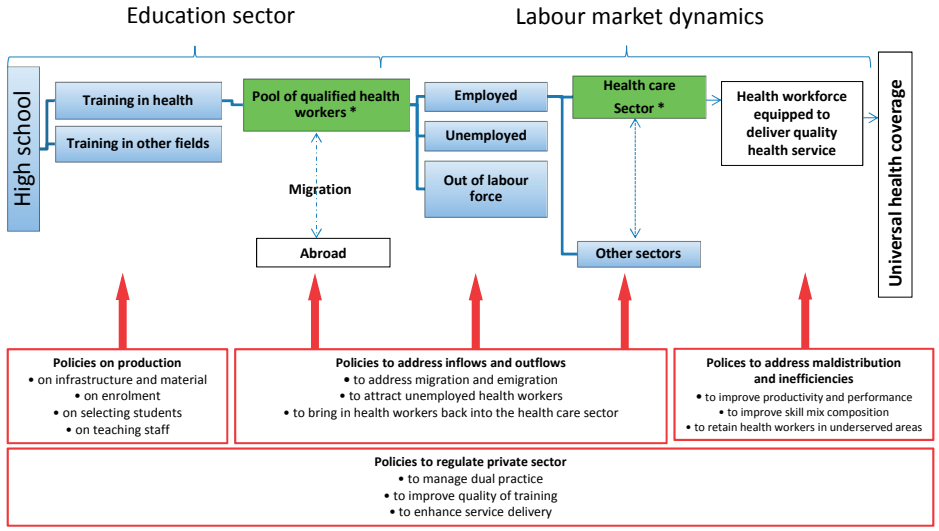
number of hours they work, their geographical distribution, their employment settings, and their productivity and performance.[5]

The health labour market framework

The framework presented in Fig. 1 provides a comprehensive picture of health labour market dynamics and of the contributions of four groups of health workforce policies to the attainment of equitable access to quality health services and UHC.

The training of health workers as defined by the education market is a key determinant of a country's supply of new graduates – and hence of the supply of health labour. Production policies are those that pertain to the opening of new training institutions, the provision of scholarships, the offer of financial incentives for teaching staff, the alignment of health worker education with the health needs of the population, and the training of new cadres of health workers. These polices will succeed in producing enough health workers to fulfil the needs of the population only if they are designed in parallel with policies to ensure the absorption of new graduates into the labour market and to correct workforce maldistribution and inefficiencies.

Figure 1 Health labour market framework and policy levers for attaining universal health coverage (UHC)



Note: The supply of health workers is made up of the pool of qualified health workers willing to work in the health-care sector. The demand for health workers is represented by the public and private institutions that constitute the health-care sector.

Source: Adapted from Vujicic 2006 and 2012.6,7

The available supply of health workers – i.e. the number of qualified health workers willing to work for the health sector – is determined by wages, working conditions, safety and career opportunities. The demand for health-care workers is determined by the needs of the population and the demand for health services. Health worker demand is represented by those private and public institutions that are willing and able to pay for health workers to staff clinics, hospitals or other parts of the health system. These institutions compete with the each other by having different wage rates, budgets, provider payment practices, labour regulations and hiring rules that compete favourably with working conditions in other labour markets in attracting health professionals, including new graduates.[8]

The available supply of health workers is undermined by migration and by the attrition of those who choose to work outside the health sector. In Kenya, for example, 61% of physicians are not willing to work in their home country under current working conditions and wages and prefer to migrate to Australia, Namibia or the United States of America.[9] Between 1990 and 2004, Zambia experienced a large exodus of physicians. To discourage physicians from leaving the country, the government increased their wages by 16% between 2007 and 2011 – to an amount 15 times the per capita income and in excess of the average pay received by other professionals with similar education, such as lawyers. Yet despite this increase, a physician's average annual wage is only 21 780 United States dollars.[10] Policies to attract health workers back to the health-care sector, discourage their migration and mobilize the unemployed, range from increasing wages and providing extra allowances to improving working conditions, revising recruitment strategies and offering training opportunities. If we are to draw closer to attaining equitable access to quality health services for the entire population, these policies will need to be designed with several factors in mind, including the geographical distribution of the current health workforce, worker productivity and performance, the skill-mix composition, and the allocation of health workers to the public and private sectors.

Although the shortage of health workers constrains service delivery, worker maldistribution, inappropriate training, poor supervision, low productivity and poor performance undermine the capacity of the existing supply of health workers to deliver quality services that are acceptable and accessible to the entire population. For example, Cameroon's capital city of Yaoundé has 4.5 times as many health workers per inhabitant as the country's poorest province.[11] Such large health workforce inequalities stem from the low retention of health workers in poorer areas, which results in less access to health services and worse health outcomes in those areas than in more prosperous ones. Several policies are designed to redress worker maldistribution and inefficiencies. They include the training of local health workers; the opening of new vacancies; the adoption of recruitment strategies to increase the supply of health workers in underserved or rural

areas; the provision of allowances; the granting of scholarships; and the matching of workers' skills and tasks. UHC cannot be attained unless health workforce inefficiencies and resource wastage are eliminated by improving health worker productivity and performance.[12]

Virtually all countries have growing private health labour markets. Policies specifically designed to regulate the private sector need to be developed to ensure equitable access to quality health services for the entire population. In Sudan, for example, 90% of health workers engage in dual practice – i.e. they work in both the private and the public sector – but they do so informally, with little regulation. This jeopardizes the availability of health workers in the public sector and the quality of public health services.[13] Staff training, service quality and dual practice are some of the areas in which regulatory policies are needed in the private health labour market.

Finally, the precise combination of health workforce policies intended to address worker shortages and maldistribution should be tailored to each country's particular context and to its population's health needs. In addition, innovative approaches such as task shifting and deployment of community health workers are needed to address inefficiencies and enhance equity in the delivery of services.

Conclusion

Health workforce policies that are partial rather than comprehensive, such as those that focus on education, are not effective in addressing health workforce shortages and ensuring equitable access to health services for a country's entire population. A health labour market framework can provide the comprehensive approach needed to fully understand the forces behind health workforce supply and demand and make it possible to develop effective health workforce polices for the attainment of UHC.

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Chapter 3

Monitoring inequalities in the health workforce: the case study of Brazil 1991-2005

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Abstract

Introduction Both the quantity and the distribution of health workers in a country are fundamental for assuring equitable access to health services. Using the case of Brazil, we measure changes in inequalities in the distribution of the health workforce and account for the sources of inequalities at sub-national level to identify whether policies have been effective in decreasing inequalities and increasing the density of health workers in the poorest areas between 1991 and 2005.

Methods With data from Datasus 2005 and the 1991 and 2000 Census we measure the Gini and the Theil T across the 4,267 Brazilian Minimum Comparable Areas (MCA) for 1991, 2000 and 2005 to investigate changes in inequalities in the densities of physicians; nurse professionals; nurse associates; and community health workers by states, poverty quintiles and urban-rural stratum to account for the sources of inequalities.

Results We find that inequalities have increased over time and that physicians and nurse professionals are the categories of health workers, which are more unequally distributed across MCA. The poorest states experience the highest shortage of health workers (below the national average) and have the highest inequalities in the distribution of physicians plus nurse professionals (above the national average) in the three years. Most of the staff in poor areas are unskilled health workers. Most of the overall inequalities in the distribution of health workers across MCA are due to inequalities within states, poverty quintiles and rural-urban stratum.

Discussion This study highlights some critical issues in terms of the geographical distribution of health workers, which are accessible to the poor and the new methods have given new insights to identify critical geographical areas in Brazil. Eliminating the gap in the health workforce would require policies and interventions to be conducted at the state level focused in poor and rural areas.

Introduction

Despite the increased evidence that health workers are fundamental for improving the levels of intervention coverage and the health of the population [1]–[7] several countries still face severe shortages of health workers [3] and in many others there are large inequalities in the distribution of the health workforce within the country [8]. Both the quantity and the distribution of health workers in a country are fundamental for assuring equitable access to health services. This is particularly important as progress towards achieving MDGs targets on maternal and child mortality has slowed down by large differentials between poor and rich populations [9].

In Brazil the main problems originate from the unequal distribution of health workers within the country. The latest data from 2007 and 2009 show that most of the nurses and physicians are concentrated in the richest areas of the country [10], [11]. Despite the last two decade major health reforms implemented in Brazil seeking to enhance the local accessibility of health services and improve the health of the poor, several studies have found that poorer populations have less access to health services and worse health than richer populations [12]–[22].

While there have been great improvements in decreasing inequalities in several health indicators and improving the socioeconomic conditions of the population [10], [20], [23], social deprivation and lack of access to health services impede 16 million people to come out of extreme poverty. A large majority of the extreme poor lives in the Northeast Region and in rural areas [24]. It is therefore crucial to measure inequalities in the distribution of the health workforce and account for the sources of the inequalities to identify critical geographical areas. Although differences in the densities of health workers between urban-rural stratum or regions have been documented few studies have been undertaken to measure and monitor inequalities in the distribution of health workers across lower geographical levels of desegregation throughout the country [11] e.g. minimum comparable areas.

In addition, new evidence has highlighted that the methods to properly measure inequalities in the distribution of the health workforce in countries have not been fully used in this domain of research. An innovative study, Anand S. 2010, shed light on this issue and found that from all the inequality indices proposed in the economic literature, three indices have been shown to be more appropriate to measure inequalities in the distribution of the health workforce and account for the sources of the inequalities in a country: the Gini, the Theil L and T indices [8].

The aim of this paper is to apply these new methods to measure the changes in the inequalities in the distribution of the health workforce at sub-national level in Brazil and account for the sources of the inequalities in a period where major health reforms have been implemented to identify whether policies have been effective in decreasing the in-

equalities in the density of health workers among the poorest and richest areas between 1991 and 2005. This study is particularly important as one of the main priorities of the Brazilian government is to eradicate extreme poverty by 2014, a recent programme was launched to provide opportunities in terms of education, health and employment to help lift people out of extreme poverty [24].

Materials and Methods

We used data from the two population Census, 1991 and 2000, [25], [26] for the 4,267 Minimum Comparable Areas (MCA) and from Datasus 2005 [27], [28] for the 27 states to investigate inequality trends in the distribution of the health workforce at sub-national level in Brazil. Minimum Comparable Areas (MCA) are the smallest geographical unit comparable across time.

The number of health workers per capita, were extracted from the 1991 and 2000 population Censuses microdata using sample weights to obtain population estimates for the 4,267 MCA. Four categories of health workers; in the form of densities per 1000 population; are used in this analysis to investigate inequalities in the distribution of the health workforce and account for the sources of these inequalities in Brazil: physicians; nurse professionals; nurse associates (defined as the number of people who reported been a technicians, auxiliaries of nursing, assistants nursing, practical midwives and similar by occupation); and community health workers.

We additionally extracted the densities of the four categories of health workers at state level for 2005 from Datasus 2005 -Conselhos profissionais (Ministério da Saúde/SGTES/DEGERTS/CONPROF) and Sistema de Informação da Atenção Básica (SIAB/ Ministério da Saúde)- to calculate the growth rates between 2000 and 2005 for each category of health workers. We then extrapolated the growth rates at state level to the 2000 Census data to calculate the densities of physicians; nurse professionals, nurse associates and community health workers for the 4,267 MCA in 2005.

We also used data on the proportion of population below the poverty line to characterize the MCA by socioeconomic status. These data were obtained from the Institute of Applied Economic Research and were estimated from the 2000 population Census of Brazil [29].

Methods

Anand S. 2010 identified three inequality indices which are more appropriate to measure inequalities in the distribution of health workers and account for the sources of the inequalities in a country: 1) the Gini coefficient, as it is a well known measure

to account for inequalities in the distribution of other indicators such as household income, however it has the disadvantage that it can not be decomposed to account for the sources of the inequalities; 2) the Theil L, as it can be decomposed in inequalities within and across sub-national areas in a country; and 3) the Theil T index, as it can also be decomposed as the Theil L index; but it has the advantage to measure inequalities when a sub-national unit does not have health workers, e.g. when there are no doctors in a MCA -further details on the methods are reported elsewhere [8]-.

We therefore applied the Gini and the Theil T to investigate inequality trends in the densities of physicians; nurse professionals; nurse associates; and community health workers across MCA in Brazil for 1991, 2000 and 2005. We measured the Theil T rather than the Theil L because in Brazil numerous MCA do not have health workers. We additionally measured the bias that could be introduced when MCA with no health workers are not accounted in the Theil T estimation. The Theil T is also measured with MCA clustered by states, poverty quintiles and urban-rural stratum to account for the sources of inequalities and identify critical geographical areas. The analysis was performed using STATA 11 [30], [31]

Results

In general we found that between 1991 and 2005 there has been an increase on the density of health workers per 1000 population in Brazil (see Table 1). The national

Table 1 Descriptive statistics.

	1991					2000					2005				
Densities	**mean**	**p50**	**sd**	**min**	**max**	**mean**	**p50**	**sd**	**min**	**max**	**mean**	**p50**	**sd**	**min**	**max**
Physicians	1.17	0.62	1.35	0.00	7.80	1.17	0.66	1.31	0.00	9.24	1.42	0.83	1.54	0.00	10.35
Nurse professionals	0.21	0.08	0.28	0.00	7.15	0.32	0.20	0.34	0.00	6.65	0.39	0.24	0.43	0.00	7.78
Nurse associates	3.06	3.07	1.80	0.00	23.89	3.56	3.58	1.75	0.00	24.95	5.50	5.39	3.12	0.00	32.69
Community health workers	0.35	0.21	0.51	0.00	12.51	0.96	0.80	0.78	0.00	16.83	1.45	1.23	1.10	0.00	23.06
Skilled HW	1.38	0.79	1.57	0.00	8.92	1.49	0.88	1.58	0.00	10.77	1.80	1.07	1.87	0.00	12.01
Not skilled HW	3.42	3.50	1.81	0.00	23.89	4.53	4.56	1.72	0.00	24.95	6.96	6.75	3.22	0.00	34.25

Sources: Data were extracted from the population Census 1991 & 2000. We also used data at state level from Datasus 2005 -Conselhos profissionais (Ministério da Saúde/SGTES/DEGERTS/CONPROF) and Sistema de Informação da Atenção Básica (SIAB)-,

Note: Skilled (HW) Health Workers is defined as physicians and nurse professionals and not skilled Health Workers as community health workers and nurse associates. Densities are calculated per 1000 pop

density of physicians plus nurse professionals per 1000 population increased from 1.38 in 1991 to 1.49 in 2000 to 1.80 in 2005. A sharper growth is found between 1991 and 2005 in the density of nurse associates plus community health workers which increased from 3.42 in 1991 to 4.53 in 2000 to 6.96 in 2005. However it is interesting to point out that in 2005 the total density of nurse professionals is the lowest with 0.39 nurses per 1000 population and that the density of nurse associates is the highest with 5.5 nurses per 1000 population.

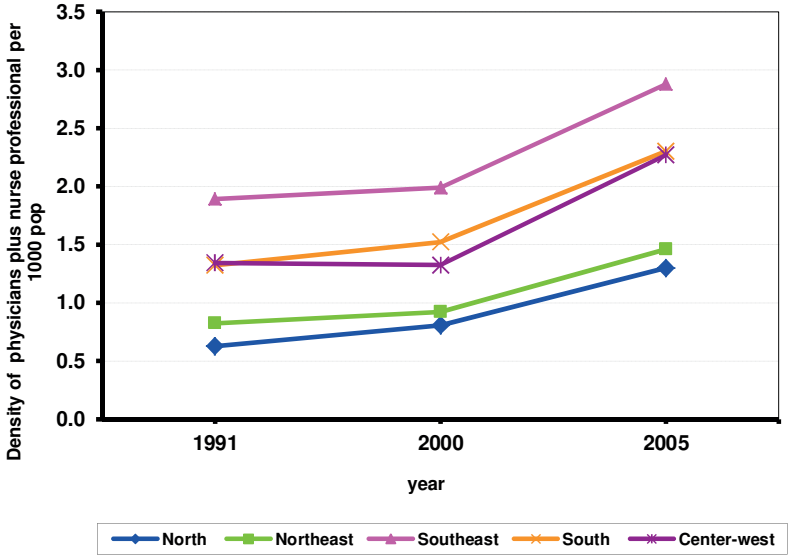
A number of policies have been implemented to increase the number of health workers between 1991 and 2005. For example, PROFAE - Projeto de Profissionalização dos Trabalhadores da Área de Enfermages was created in 2000 with the aim to increase the supply of nurse associates in the country. The main target was to train 225 000 mid-level nurses and 12,000 teaching nurses. Since the project was implemented even more providers have been trained, the latest data from 2008 shows that 235,172 nurses have graduated as nurse associates [32], [33].

For this analysis we grouped physicians together with nurse professionals as in Brazil these categories of health workers are considered as skilled health workers as they have university education, while nurse associates and community health workers have high school and vocational courses and therefore are considered as non skilled health workers.

Although there has been a very important increase in the number of health workers the absolute differences show that there is great variability in the densities of health workers across regions, states and MCA in the period analysed. Figure 1 shows the differences in the trends of the densities of physicians plus nurse professionals by region between 1991 and 2005. We found that the richest Regions (South and Southeast) have more skilled health workers and at the same time have experienced a sharper growth in the densities of these categories of health workers between1991 and 2005 than the poorest Regions (North and Northeast). We also found great differences across MCA, 61% of the MCA did not have physicians plus nurse professionals in 1991 and 53% in 2005, compare to some areas that had densities above 9 per 1000 pop.

We applied the Gini, and the Theil T indices to investigate inequality trends in the distribution of health workers across MCA, for 1991, 2000 and 2005 (see Table 2). In general, we found that the overall inequalities in the distribution of physicians, nurse professionals, nurse associates and community health workers have decreased between 1991 and 2000. However, between 2000 and 2005, we found that inequalities have increased in the distribution of nurse professionals and nurse associates, have remained the same for the density of physicians and have steadily decreased over time for community health workers. We nevertheless found that physicians and nurse professionals are the categories of health workers which are the most unequally distributed across MCA. The Gini for nurse professionals in 1991 is .66, in 2000 is .57 and in 2005 is .59 while the Gini for physicians in 1991 is .60, and is .58 in 2000 and 2005.

Figure 1. Trends of the density of physicians plus nurse professional per 1000 pop by region in Brazil 1991–2005.



Author's calculation using data of the population Census 1991 & 2000 and Datasus 2005 -Conselhos profissionais (Ministério da Saúde/SGTES/DEGERTS/CONPROF). Note: X axis = year. Y axis = density of physicians plus nurse professionals per 1000 pop. Blue diamond = North Region. Green square = Northeast Region. Purple cross = Centre West Region. Yellow cross = South Region. Pink triangle = Southeast Region. doi:10.1371/journal.pone.0033399.g001

The main advantages of the Theil T are that it can be decomposed in inequalities within and across sub-national areas to identify the sources of the inequalities in a country and it can also be measured when MCA do not have health workers. We then measured the percentage of underestimation if MCA with no health workers were not included in the calculations and found that 42% of overall inequality in the distribution of physicians and 60% in the distribution of nurse professionals in 2005 is due to MCA with no health workers.

We clustered MCA by different population subgroups to identify the sources of the inequalities. We first started with the partition of MCA by state and found that most of the overall inequalities in the distribution of health workers across MCA are due to inequalities within states which account for around 60% to overall inequality and this has not changed over time. Moreover we found that in general within state inequalities have increased in time. For both physicians plus nurse professionals inequalities within states accounted for 81% of the overall inequality in 1991 and it increased to 83% in 2005. The opposite tendency is found for nurse associates plus community health workers where the percentage of within states inequality to overall inequality was 80% in 1991, 92% in 2000 and it decreased to 74% in 2000.

Table 2. Inequalities in the distribution of the health workforce and the sources of the inequalities by category of health workers in Brazil 1991–2005.

	1991					2000					2005				
Densities	**Gini**	**Theil T**	**Theil within (%)**	**Theil between (%)**	**bias (%)**	**Gini**	**Theil T**	**Theil within (%)**	**Theil between (%)**	**bias (%)**	**Gini**	**Theil T**	**Theil within (%)**	**Theil between (%)**	**bias (%)**
Physicians	0.60	0.64	0.38 (60)	0.26 (40)	0.28 (44)	0.58	0.60	0.36 (60)	0.24 (40)	0.25 (41)	0.58	0.59	0.50 (84)	0.10 (16)	0.25 (42)
Nurse professionals	0.66	0.85	0.65 (76)	0.20 (24)	0.61 (71)	0.57	0.61	0.47 (77)	0.14 (23)	0.39 (64)	0.59	0.65	0.58 (89)	0.07 (11)	0.39 (60)
Nurse associates	0.33	0.19	0.12 (64)	0.07 (36)	0.03 (16)	0.28	0.13	0.08 (63)	0.05 (37)	0.01 (8)	0.30	0.16	0.11 (73)	0.04 (27)	0.01 (7)
Community health workers	0.63	0.75	0.68 (90)	0.07 (10)	0.32 (42)	0.42	0.30	0.23 (75)	0.08 (25)	0.05 (17)	0.38	0.26	0.21 (83)	0.04 (17)	0.05 (20)
Poverty quintiles															
Skilled HW	0.59	0.62	0.38 (60)	0.25 (40)	0.26 (42)	0.55	0.54	0.33 (61)	0.21 (39)	0.19 (35)	0.55	0.54	0.34 (63)	0.20 (37)	0.19 (35)
Not skilled HW	0.29	0.15	0.11 (73)	0.04 (27)	0.02 (12)	0.21	0.08	0.06 (82)	0.01 (18)	0.00 (4)	0.24	0.10	0.09 (85)	0.02 (15)	0.00 (3)
Stratum (Uban-rural)															
Skilled HW	0.59	0.62	0.48 (77)	0.15 (23)	0.26 (42)	0.55	0.54	0.46 (85)	0.08 (15)	0.19 (35)	0.55	0.54	0.46 (85)	0.08 (15)	0.19 (35)
Not skilled HW	0.29	0.15	0.12 (79)	0.03 (21)	0.02 (12)	0.21	0.08	0.07 (88)	0.01 (12)	0.00 (4)	0.24	0.10	0.09 (91)	0.01 (9)	0.00 (3)
States															
Skilled HW	0.59	0.62	0.51 (81)	0.12 (19)	0.26 (42)	0.55	0.54	0.45 (83)	0.09 (17)	0.19 (35)	0.55	0.54	0.47 (83)	0.07 (17)	0.19 (35)
Not skilled HW	0.29	0.15	0.12 (80)	0.03 (20)	0.02 (12)	0.21	0.08	0.07 (92)	0.01 (8)	0.00 (4)	0.24	0.10	0.08 (74)	0.03 (26)	0.00 (3)

Sources: Author's calculation using data of the population Census 1991 & 2000, Datasus 2005 -Conselhos profissionais (Ministério da Saúde/SGTES/DEGERTS/CONPROF) and Sistema de Informação da Atenção Básica (SIAB/ Ministério da Saúde)-, and the Institute of Applied Economic Research (IPEA).

Note: Skilled (HW) Health Workers is defined as physicians and nurse professionals and not skilled Health Workers as community health workers and nurse associates. Densities are calculated per 1000 pop

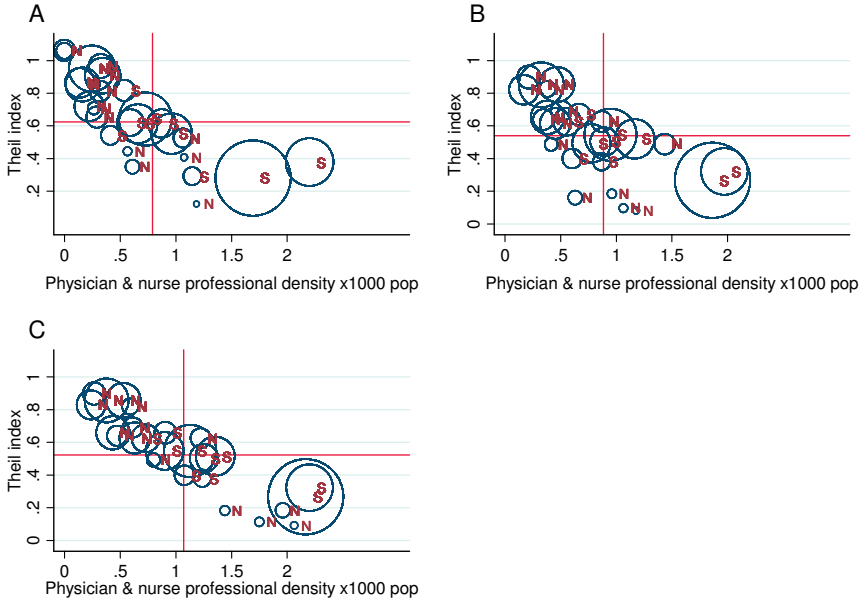
We also measured inequalities by poverty quintiles and found contrary to what was expected that inequalities between the poor and rich are not that high; most of the total inequality is explained by inequalities within poverty quintiles and this is encountered for the three years analysed. For physicians plus nurse professionals the between poverty quintile inequalities accounts for only 37% of overall inequality and most of the overall inequality (63%) is due to inequalities within poverty quintiles. In fact, the highest inequalities are found within the poorest quintile. For nurse associates plus community health workers the percentage contribution of between poverty quintiles to overall inequality is even smaller and has decreased in the period analysed, from 27% in 1991 to 15% in 2005. Similarly, Anand S. 2010, found that inequalities between income deciles explain only 20% of the total inequality in rural counties in China.

In the partition of MCA by urban-rural stratum we found that most of the overall inequality in the distribution of physicians plus nurse professionals across MCA is due to inequalities within urban-rural stratum, which account for around 77% to overall inequality in 1991 and this percentage has increased to 85% in 2005. The highest inequalities are found within the rural stratum. For nurse associates plus community health workers we found the same trend, the within urban-rural stratum accounts for 79% of the overall inequality in 1991 and this percentage increased to 91% in 2005.

Figure 2 shows the relationship between the level of inequality and the density of both physicians plus nurse professionals by state and region for 1991 (A), 2000 (B) and 2005 (C). The horizontal and vertical lines in A, B and C represent the national averages of both variables. We found that the majority of the states which belong to the poorest regions (North and Northeast Regions) experienced the highest shortage of health workers; with densities below the national average; and at the same time have the highest inequalities in the distribution of physicians plus nurse professionals; with inequalities above the national average in the three years analysed. These states are also among the poorest states with the highest population density. In contrast we found that states in richer regions (South, Southeast and Central West Regions) have the lowest inequalities (below the national average) and the highest numbers of physicians plus nurse professionals per 1000 pop (above the national average).

Although most of the poorest states have high inequality in the distribution of physicians and nurse professionals it is important to highlight that some states have attained very important progresses in decreasing the level of inequality and decreasing the shortage of physicians and nurse professionals per 1000 pop. For example, the states of Amapá which has decreased the level of inequality from .41 in 1991 to .11 in 2005 and Alagoas which has decrease the level of inequality from 1.06 to .69 and has also increased the density of physicians plus nurse professionals. Progress in these states are mainly due to a higher increase in their financial resources to human resources for health in the period analysed. The state of Amapa experienced an increase in all health resources as between

Figure 2. Relationship between the level of inequality and the density of physicians plus nurse professionals per 1000 pop by state and region in Brazil 1991–2005.



Author's calculation using data of the population Census 1991 & 2000 and Datasus 2005 -Conselhos profissionais (Ministério da Saúde/SGTES/DEGERTS/CONPROF). Note: X axis = density of physicians plus nurse professionals per 1000 pop. Y axis = Theil T index. Panel A = relationship for the year 1991. Panel B = relationship for the year 2000. Panel C = relationship for the year 2005. Each dot represents a state. The horizontal and vertical line represents the national averages of both variables. S refers to states in the Southern Regions and N refers to states in the Northern Regions. Area of the symbol proportional to state's population. doi:10.1371/journal.pone.0033399.g002

1991 and 2005 it benefited from the highest increase (more than three times) of federal funds allocated to health. It is important to highlight that in 1991, it was also the sate which received the least resources from the federal government. In the case of Alagoas progress towards decreasing inequalities are mainly due to the fact that it is among the states with the highest increased in the allocation of health expenditure to human resources for health an increase of more than 1.3 times between 1991 and 2005 [34].

Discussion

We found that between 1991 and 2005 there have been great improvements in increasing the availability of health workers in Brazil. However, despite these improvements, we found that the overall inequalities in the distribution of health workers have increased between 2000 and 2005, except for community health workers which have experienced

a decrease over time. Physicians and nurse professionals are the categories of health workers which are more unequally distributed across MCA.

Despite the efforts made by the Brazilian government to enhance the local accessibility of health services particularly among the poor, we found that the poorest states -from the North and Northeast Regions- experienced the highest shortage of health workers and at the same time have the highest inequalities in the distribution of skilled health workers such as physicians and nurse professionals and this problem has not changed over time. The majority of the staff in these geographical areas are nurse associates and community health workers which have less skills and education.

We also found that most of the overall inequalities in the distribution of health workers across MCA are due to inequalities within states, within poverty quintiles and within rural-urban stratum and this has not changed over time. Thus policies and interventions should be directed to increase the availability of health workers in poor and rural areas at state level.

This study has highlighted some critical issues in terms of the geographical distribution of skilled health workers and the new methods have given new insights to identify critical geographical areas in Brazil. Although geographical areas with more health workers are more likely to have better population health further analysis should be undertaken to compare health outcomes between areas with varying levels of skilled health workers to determine if there are direct measurable effects of health workers supply and skilled mix composition in the health of the population. This type of analysis is essential to advance the knowledge on the type of health system policies that could have a direct effect in improving the health of the poorest population. In this critical point in time when we are approaching the 2015 deadline to attain the Millennium Development Goals (MDGs) targets, it is crucial that countries share experiences in policies that have been effective in improving the health of the poorest populations.

The conclusions drawn from this study should take into consideration the limitations of the data. Although municipality is the geographical unit where decisions are made after the decentralization reform, we did not used municipalities in this analysis as it is a geographical unit that is not comparable over time. This is because a number of municipalities have been created between 1991 and 2000, from 4,491 to 5,507. To overcome this problem we used data for MCA (4,267) as it is the smallest geographical unit that is comparable over time. We produced estimates for the MCA for 2005 from the 2000 population census as the censuses are the sources of information with more consistent data on the variables used in this study for the minimum comparable areas. We used the information from Datasus to produce the 2005 data as we compared the densities of physicians and nurse professionals from other sources at state level and found that Datasus is the only source that produces similar densities of health workers than the population Census. Since we used data at state level to extrapolate the densities

of the different type of health workers at MCA in this study it is probable that the densities at the MCA level may differ from the current numbers.

The results found in this study are in line with recent studies, which showed great inequalities in the distribution of health workers across region using more recent data from 2007 [10]. Given the last years expansion of investment in the poorest regions -North and Northeast-, with strategies such as the Health family Programme to increase the availability of family health teams and increase coverage of health services, [35], further analyses using the methods presented in this paper will be key to monitor the impact of these policies to decrease inequalities in the distribution of health workers at sub-national level. This will be possible when the more recent Census data will be available in 2012.

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Part II

Health service utilization

Chapter 4

Exploring the determinants of unsafe abortion: improving the evidence base in Mexico

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Abstract

Background Despite the realized importance of unsafe abortion as a global health problem, reliable data are difficult to obtain, especially in countries where abortion is illegal. Estimates for most developing countries are based on limited and incomplete sources of data. In Mexico, studies have been undertaken to improve estimates of induced abortion but the determinants of unsafe abortion have not been explored.
Methods We analysed data from the 2006 Mexican National Demographic Survey. The sample comprises 14 859 reported pregnancies in women between 15 and 55 years old, of which 966 report having had an abortion in the 5 years preceding the survey. We use logistic regression to explore the relationship between unsafe abortion and various socio-economic and demographic characteristics.
Findings We estimate that 44% of abortions have been induced and 16.5% of those were unsafe. We find three variables to be positively and significantly associated with the probability of having an induced abortion: (1) whether the woman reported that the pregnancy was mistimed (OR = 4.5, 95% CI = 1.95–10.95); (2) whether the woman reported that the pregnancy was unwanted (OR = 2.86, 95% CI = –1.40–5.88); and (3) if the woman had three or more children at the time of the abortion (OR = 3.73, 95% CI = 1.20–11.65). There is a steep socio-economic gradient in the probability of having an unsafe abortion: poorer women are more likely to have an unsafe abortion than richer women (OR = 2.48, 95% CI = 1.09–5.63); women with 6–9 years of education (OR = 0.30, 95% CI = 0.11–0.81) and with more than 13 years of education are less likely to have an unsafe abortion (OR = 0.065, 95% CI = 0.01–0.43), and women with indigenous origin are more likely to have an unsafe abortion (OR = 5.44, 95% CI = 1.91–15.51). Thus, the probability for poor women with less than 5 years of education and indigenous origin is nine times higher compared with rich, educated and not indigenous women. We also find marked geographical inequities as women living in the poorest states have a higher risk of having an unsafe abortion.
Interpretation This analysis has explored the determinants of unsafe abortion and has demonstrated that there are large socio-economic and geographical inequities in unsafe abortions in Mexico. Further efforts are required to improve the measurement and monitoring of trends in unsafe abortions in developing countries.

Key messages

- This paper quantifies for the first time the large socio-economic and geographical inequities in unsafe abortions in Mexico.
- The burden of unsafe abortions is disproportionately born by poor, less educated and indigenous women. Women living in the poorest states have a higher risk of having an unsafe abortion.

Background

The critical relationship between unsafe abortion and the attainment of the Millenium Development Goals (MDGs) has been highlighted in recent studies (Fathalla et al. 2006; Glasier et al. 2006; Grimes et al. 2006; Ronsmans and Graham 2006). Reducing unsafe abortions and the complications resulting from them is not only closely linked to the health-related MDGs, such as the reduction of maternal mortality, but also to the MDGs related to other aspects of development, including poverty reduction, gender equality and women's empowerment. Monitoring trends in unsafe abortion practices as well as sharing countries' experience on policies and interventions that have been successful in reducing unsafe abortions is crucial, as the half-way point towards achieving the MDGs has been reached.

It is estimated that 22% of all pregnancies worldwide end in an induced abortion—approximately 50 million each year around the year 2000 (Guttmacher Institute 1999). About 20 million of these abortions are estimated to be performed in unsafe conditions, and almost all of them (97%) take place in developing countries (Henshaw et al. 1999). The number of women who die from an unsafe abortion each year is estimated to be 68 000, accounting for 13% of all maternal deaths around the world, and 17% in Latin America (World Health Organization 2004; Khan 2005), with a median unsafe abortion mortality ratio of 34 per 100 000 live births in countries where abortion is illegal (Berer 2004).

In Mexico, induced abortion is illegal. In some states abortion is legal when a woman has been raped, her life or health are in danger, or when there are foetal defects, and under request within the first 12 weeks of pregnancy in the Federal District (where abortion was recently legalized) (GIRE 2005; Organo del Gobierno del Distrito Federal 2007). However, even in those circumstances, access to safe abortion is not guaranteed, as doctors in public facilities can refuse to perform the procedure (Human Rights Watch 2006). According to government statistics, abortion-related complications in public hospitals are the third most common cause of hospitalization among women of reproductive age and account for 7.3% of all maternal deaths (Secretaria de Salud 2002b; Secretaria de Salud 2004).

Reducing maternal mortality and morbidity in Mexico has been a priority for the government in recent years. Unsafe abortion and its complications have been acknowledged as an important public health problem, but reliable data to monitor and evaluate its effects are difficult to obtain. Previous studies in Mexico used indirect methods to estimate the number of abortions, varying between 110 000 (CONAPO 1996) and 533 000 in 1990 (Henshaw et al. 1999). However, such indirect methods have been criticized for suffering from measurement error (Reinis 1992). Other studies in Mexico using population-based surveys (Nunez and Palma 1994; Lara et al. 2006a) are considered as a

better source of information to study the incidence and prevalence of induced abortion (Lara et al. 2004; Lara et al. 2006a). The most recent study estimated a prevalence rate of induced abortion of 16.3% for women between 15 and 55 years old for 2005 (Lara et al. 2006a). Although these studies further explore and identify the characteristics of women who have had an induced abortion in Mexico, they do not provide information on the place and safety of the procedure or on the characteristics of women who had unsafe abortions.

In 2006, the National Demographic Survey (ENADID) included questions on abortions as part of the pregnancy calendar. This is the first time that a population-based survey in Mexico has included direct questions about abortion. Information was collected for the most recent abortion reported for each respondent on the type of provider, facility and technique, and whether the pregnancy was wanted or not. Information was also collected on the socio-economic and demographic characteristics of the respondent. In this paper we explore the ENADID survey to identify the determinants of unsafe abortion.

Methods

Data

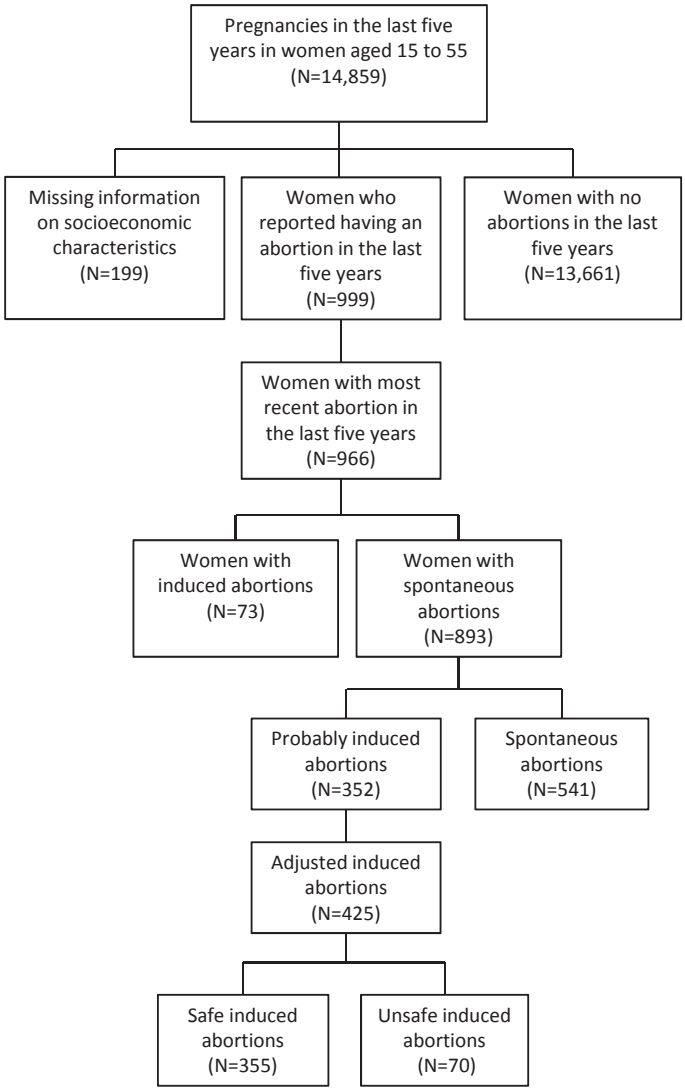
Data for this study come from the ENADID survey (Encuesta Nacional de Dinamica Demografica which was conducted in 2006 (INEGI 2006). ENADID is an interviewer-administered household survey which is representative at state level. It is designed to collect detailed information on women aged between 15 and 55 years on social and demographic characteristics, child health and a range of reproductive health issues, including family planning, fertility, contraceptive knowledge and use. In addition, it collects information on household characteristics, including ownership of consumer goods, household services and place of residence.

In the women's questionnaire, respondents who have ever been pregnant were asked to report on all their pregnancies. For each pregnancy, women were asked to provide information on whether it ended in an abortion (defined in this survey as pregnancy termination up to 5 months of gestation), the date of abortion and the gestational age at the time of the abortion. Women who reported having had an abortion were asked more detailed questions on the most recent abortion. Respondents were asked: (1) if the abortion was a mistimed or unwanted birth, (2) whether the abortion was spontaneous, induced by medication, induced by injection or other procedure, (3) the type of provider who performed the abortion (doctor, nurse, auxiliary worker, traditional birth attendant, the respondent herself or other) and (4) the facility where the abortion was

performed (social security, public or private clinic or hospital, traditional birth attendant's residence or in the respondent's home). The survey did not collect information on the reason for the termination of the pregnancy or on the use of contraception methods during the cycle of conception.

The total sample is 38 661 women between 15 and 55 years old. We limited the analysis to women who reported having an abortion during the 5 years preceding the survey to avoid recall bias problems with reporting on events that happened in the distant past.

Figure 1 Flow diagram of information



Of the 14 859 reported pregnancies in the last 5 years in women 15–55 years old, 999 ended in abortion and had complete information on the socio-economic and demographic characteristics used in the analysis. Among these 999 abortions, 966 were identified as the most recent abortion, which entails that the difference (of 33 abortions) represents women with more than one abortion. Figure 1 shows the flow diagram of information.

Definition of unsafe abortions

Unsafe abortions are characterized by the lack or inadequacy of skills of the provider, hazardous techniques and/or unsanitary facilities (World Health Organization 1994). WHO defines an unsafe abortion as a 'procedure for terminating an unintended/unwanted pregnancy either by individuals without the necessary skills or in an environment that does not conform to minimum medical standards, or both' (World Health Organization 1992). The types of health worker that have the necessary skills vary according to the medical and legal standards of each country. In Mexico only doctors are formally trained to perform abortions and to deal with the complications of incomplete abortions.

Using the WHO definition, we classified an induced abortion as unsafe if it was performed by an unskilled provider (the woman herself, a traditional birth attendant, an auxiliary worker, nurse or provider other than a doctor) and/or if it was performed in an unsanitary facility (the woman's home, the traditional birth attendant's home or other) and/or if it was performed using a hazardous technique (caused by an ingestion of a harmful substance, voluntary trauma or injury by fall) (Guttmacher Institute 1999). Induced abortions performed in public facilities were classified as safe as there is no information to verify if these were abortions attempted elsewhere in which complications ensued and which then ended up being treated in public facilities.

Analysis

We compared the distribution of pregnancy losses by gestation age at termination of pregnancy in our sample with the distribution in the study by Shapiro and colleagues (Shapiro et al. 1962). They found, as did several other studies, that most of the intrauterine mortality happened in the first weeks of gestation (Shapiro et al. 1962; Leridon 1977; Wilcox et al. 1981). In general, we found in our sample a larger concentration of abortions in the third and fourth month of gestation, between 7% and 12% more abortions than Shapiro et al. We argue that these differences are probably due to misreporting of induced abortions.

Under-reporting and misreporting of induced abortions is common in countries where abortion is illegal. In a study of 118 women who reported a spontaneous abortion in Merida, Mexico, 77% later admitted that the abortion had been induced (Canto de Cetina et al. 1985). Several strategies have been used in previous studies to identify abortions that have likely been induced, although there is no gold standard method (Talamanca and Repetto 1988; Magnani et al. 1996; World Health Organization 1996; Rasch et al. 2000). WHO proposed a classification scheme for categorizing hospitalized cases of abortion (World Health Organization 1996) and Magnani et al. proposed a scheme for classifying abortions that are reported in DHS calendar information (Magnani et al. 1996). According to the WHO classification, certainly induced abortions are those the woman herself reports having been induced (World Health Organization 1996). The corrected number of induced abortion is the sum of the certain cases of induced abortions plus the cases considered to be probably induced.

In this analysis we used two logistic regression models. The first model was used to identify the suspected cases of induced abortions that were reported as spontaneous abortions. The second model was used to estimate the probability of having an unsafe abortion among the adjusted number of induced abortions.

In the first model, we explored the probability of having an induced abortion among all abortions (spontaneous and induced) using a logistic regression. The explanatory variables were age at the time of the abortion, number of children at the time of the abortion, whether the pregnancy was wanted, mistimed or unwanted, whether this abortion was the first one the woman had ever had, gestational age and marital status. We additionally considered as covariates in our analysis whether the household was poor or not (defined through a measurement of household wealth explained in the Appendix), urban or rural residence, years of education and indigenous origin.

We used the variables that were significantly positively associated with the probability of having an induced abortion in the first model to reclassify some of the reported spontaneous abortions as probably induced abortions. The adjusted numbers of induced abortions is therefore the sum of the reported cases of induced abortions and the probably induced abortions (identified in the first regression model).

In a second model, we explored the determinants of unsafe abortion among the adjusted number of induced abortions also using logistic regression. The explanatory variables in the model were whether the household was poor or not, urban/rural residence, years of education, indigenous origin, age at the time of the abortion, marital status, number of children at the time of the abortion and whether this abortion was the first one the woman had ever had. Based on the results of this logistic regression model and using Clarify (a software program for data simulation), we predicted the probability of having an unsafe abortion and the uncertainty around it, and examined trends among determinants of interest (King et al. 2000; Tomz et al. 2003).

Table 1. Indicators of abortion, induced abortion and unsafe abortion as used in this study. The survey questions used as well as the sample sizes are shown

Term	Survey questions	Population	Population 'at risk'
Abortion	5.4. Have you ever been pregnant? (1) yes, (2) no. *If 'yes':* 5.17 Have you ever had an abortion? (1) yes, (2) no.	999 women who report having an abortion in the 5 years preceding the survey.	14 859 pregnant women 15–55 years old.
Reported induced abortions	6.8 Was the most recent abortion: (1) spontaneous, (2) induced by medication, (3) induced by injection, or (4) induced by other procedure, such as curettage, injury, voluntary trauma, ingestion of a harmful substance.	73 women reported having an induced abortion (response 2, 3 or 4 to question 6.8).	966 most recent abortions in the 5 years preceding the survey.
Corrected induced abortion	6.8 Was the abortion: (1) spontaneous, (2) induced by medication, (3) induced by injection, or (4) induced by other procedure, such as curettage, injury, voluntary trauma, ingestion of a harmful substance. 6.7 Was the terminated pregnancy: (1) planned, (2) mistimed or (3) unwanted.	425 women—sum of the reported induced abortions (response 2, 3 or 4 to question 6.8) plus the probably induced abortions, which are all those spontaneous abortions for which the pregnancy is reported as mistimed or unwanted (response 2 or 3 to question 6.7) or the women had more than three children at the time of the abortion.	966 most recent abortions in the 5 years preceding the survey.
Unsafe abortion	6.9. Who attended the abortion: (1) doctor, (2) nurse, (3) auxiliary worker, (4) traditional birth attendants, (5) yourself, or (6) other. 6.10. What type of facility was the abortion performed in: (1) social security hospital or clinic, (2) public hospital or clinic, (3) private hospital or clinic, (4) traditional birth atendant's home, (5) woman's home, or (6) other. 6.8 Was the abortion: (1) spontaneous, (2) induced by medication, (3) induced by injection, or (4) induced by other procedure, such as curettage, injury, voluntary trauma, ingestion of a harmful substance.	70 women with induced abortion (corrected estimate) who had an unsafe abortion. Unsafe is defined as: abortions performed by unskilled providers (response 2, 3, 4, 5 or 6 to question 6.9); and/or abortions performed in unsanitary facilities (response 4, 5 or 6 to question 6.10.); and/or using hazardous techniques (response 4 to question 6.8).	425 induced abortions (adjusted estimate).

Table 1 shows the indicators used in this analysis, the corresponding sample sizes from the ENADID (see also Figure 1 for a flow diagram of information) and the survey questions used.

The analyses in this paper were conducted using STATA (version 9.2) (StataCorp. 2005) and are presented in the following section.

Results

Table 2 shows the numbers and percentages of women aged 15–55 with pregnancies in the last 5 years, women who reported an abortion in the last 5 years, women who reported a most recent abortion in the last 5 years, women who reported an induced abortion and the adjusted number of induced abortions by socio-economic and demographic characteristics. In our sample 6.5% of women aged between 15 and 55 years who had been pregnant reported having an abortion in the last 5 years.

Table 2. Numbers and percentages of all women aged 15–55 years with pregnancies in the last 5 years, women who reported an abortion in the last 5 years, women who reported an induced abortion, and adjusted women with induced abortion by socio-economic and demographic characteristics

	Pregnancies in last 5 years in women aged 15–55[a]		Women who reported having an abortion in last 5 years		Women who reported having most recent abortion in last 5 years		Women who reported having an induced abortion in last 5 years		Adjusted women with induced abortion in last 5 years[b]	
Variable name	Sample	%	Sample	%	Sample	%	Sample	%	Sample	%
Economic status										
Non-poor	6741	46	537	53.8	522	54	50	68.5	229	53.9
Poor	7919	54	462	46.3	444	46	23	31.5	196	46.1
Education										
≤5 years	2688	18.3	145	14.5	135	14	10	13.7	80	18.8
6–9 years	7792	53.2	518	51.9	494	51.1	39	53.4	230	54.1
10–12 years	2843	19.4	227	22.7	221	22.9	12	16.4	74	17.4
≥13 years	1337	9.1	109	10.9	116	12	12	16.4	41	9.7
Age group (at time of abortion)										
15–19 years	898	6.1	160	15.9	144	14.7	13	17.8	55	12.9
20–24 years	3476	23.5	211	21	205	21	13	17.8	67	15.8
25–34 years	7513	50.8	447	44.5	448	45.8	39	52.1	193	45.4
35–55 years	2888	19.5	187	18.6	181	18.5	9	12.3	110	25.9
Marital status										
Married	12 730	86.8	886	88.7	862	89.2	64	87.7	368	86.6
Single, divorced, widowed	1930	13.2	113	11.3	104	10.8	9	12.3	57	13.4
No. of children (at time of abortion)										
0	132	0.9	299	29.9	280	29	17	23.3	62	14.6
1	3424	23.4	278	27.8	264	27.3	21	28.8	82	19.3
2	4740	32.3	234	23.4	232	24	19	26	91	21.4
≥3	6364	43.4	188	18.8	190	19.7	16	21.9	190	44.7

Table 2 (continued)

	Pregnancies in last 5 years in women aged 15–55[a]		Women who reported having an abortion in last 5 years		Women who reported having most recent abortion in last 5 years		Women who reported having an induced abortion in last 5 years		Adjusted women with induced abortion in last 5 years[b]	
Variable name	Sample	%	Sample	%	Sample	%	Sample	%	Sample	%
Planned pregnancy										
Wanted	–	–	–	–	679	70.3	39	53.4	–	–
Mistimed	–	–	–	–	88	9.1	10	13.7	–	–
Unwanted	–	–	–	–	199	20.6	24	32.9	–	–
Months of pregnancy										
1	–	–	161	16.1	152	15.7	11	15.1	69	16.2
2	–	–	325	32.5	318	32.9	33	45.2	136	32
3	–	–	348	34.8	333	34.5	19	26	135	31.8
≥4	–	–	165	16.5	163	16.9	10	13.7	85	20
No. of abortions										
>1	–	–	308	30.8	215	22.3	21	28.8	96	22.6
1	–	–	691	69.2	751	77.7	52	71.2	329	77.4
Indigenous population										
Not indigenous	13 491	92	942	94.3	913	94.5	70	95.9	397	93.4
Indigenous	1169	8	57	5.7	53	5.5	3	4.1	28	6.6
Area of residence										
Rural area	4597	31.4	283	28.3	265	27.4	12	16.4	109	25.7
Urban area	10 063	68.6	716	71.7	701	72.6	61	83.6	316	74.4
Total sample	14 859		999		966		73		425	

[a]The variables of age group and number of children are information reported at the time of the survey.
[b]Adjusted number includes reported induced abortions and predicted induced abortions based on the logistic regression model shown in Table 3.

Out of 966 women who reported having had an abortion in the past 5 years, 7.6% (73 cases) reported that their most recent abortion was induced. Table 3 shows the first logistic regression model to estimate the probability of having an induced abortion among all abortions. After controlling for other socio-economic characteristics, the probability of having an induced abortion is significantly related to whether the woman reported that the pregnancy was mistimed or unwanted, and if the woman had three or more children at the time of the abortion. Abortions in pregnancies that were mistimed are 4.5 times more likely to be induced compared with abortions in wanted pregnancies (OR = 4.5, 95% CI = 1.95–10.95); pregnancies that were unwanted are almost 3 times more likely to be induced compared with abortions in wanted pregnancies (OR = 2.86, 95% CI = –1.40–5.88); and abortions in women with three or more children are almost

Table 3. Logistic regression results on the probability of reporting an abortion as induced, among women who report having had an abortion (966 women)

Variable name	Odds ratio	95% CI
Economic status		
Non-poor (ref)	1	
Poor	0.416*	0.19–0.92
Education		
<5 years (ref)	1	
6–9 years	0.422	0.15–1.23
10–12 years	0.278*	0.09–0.88
≥13 years	0.744	0.24–2.35
Age group (at time of abortion)		
15–19 years	1.734	0.56–5.37
20–24 years (ref)	1	
25–34 years	1.095	0.43–2.77
35–55 years	0.385	0.10–1.45
Marital status		
Married (ref)	1	
Single, divorced, widow	0.77	0.34–1.74
No. of children (at time of abortion)		
0 (ref)	1	
1	1.839	0.71–4.78
2	2.054	0.73–5.76
≥3	3.738*	1.20–11.65
No. of abortions		
>1 (ref)	1	
1	0.65	0.32–1.32
Planned pregnancy		
Wanted (ref)	1	
Mistimed	4.520***	1.95–10.45
Unwanted	2.867**	1.40–5.88
Months of pregnancy		
1 (ref)	1	
2	1.472	0.60–3.62
3	0.877	0.33–2.29
≥4	0.961	0.34–2.73
Indigenous population		
Not indigenous (ref)	1	
Indigenous	0.265	0.05–1.30
Area of residence		
Rural area (ref)	1	
Urban area	1.904	0.78–4.67
Sample	966	

*P < 0.05; **P < 0.01; ***P < 0.001.

(ref) = reference group.

4 times more likely to be induced compared with women with no children at the time of the abortion (OR = 3.73, 95% CI = 1.20–11.65).

Table 3 also shows that socio-economic status and years of education were negatively and significantly associated with the probability of reporting an abortion as induced. Poorer women are 58% less likely to have an induced abortion than richer women (OR = 0.42, 95% CI = 0.19–0.92). Similarly, women with 10–12 years of education are 72% less likely to have an induced abortion than women with no years of education (OR = 0.28, 95% CI = 0.09–0.88).

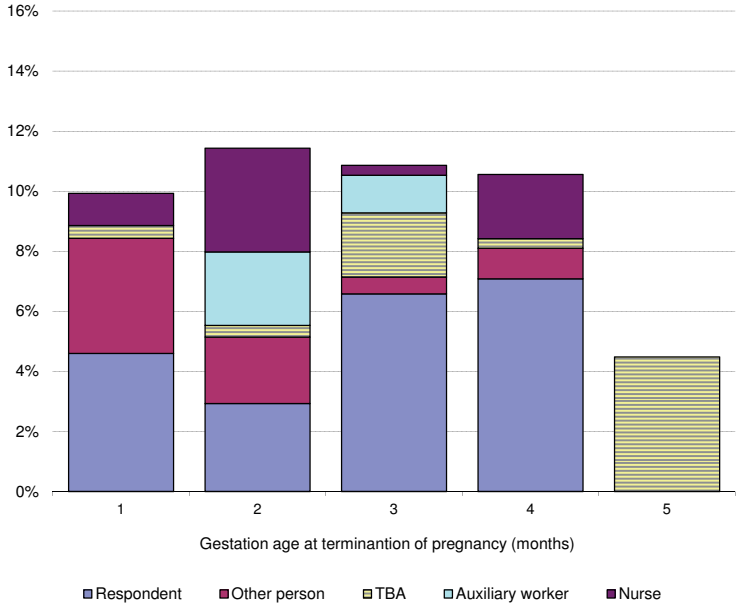
Based on the results of this regression model, we reclassified abortions as 'probably induced' if they were reported to be spontaneous and the pregnancy was reported as mistimed or unwanted or if the women had more than three children at the time of the abortion. From the 893 cases reported as spontaneous abortions, 39% (352 cases) were reclassified as probably induced. We created a measurement of adjusted numbers of induced abortions as the sum of the reported cases of induced abortions (73 cases) and probably induced abortions (352 cases). Then the adjusted number of induced abortions is estimated to be 425, which represents 44% of all abortions. Consistent with our findings, a recent study in Peru, where abortion is also illegal, found that 53% of all abortions were induced (Bernabe-Ortiz et al. 2009). Subsequent analyses referring to induced abortions use the adjusted estimate.

In our sample, 16.5% (70 cases) of induced abortions (425 cases) were identified as unsafe. Among unsafe abortions, 23% (16) employed hazardous techniques and 77% (54) took place in facilities considered as unsafe and/or were performed by unskilled providers.

Figure 2 shows the proportion of induced abortions (425 cases) performed by unskilled providers by gestation age at termination of pregnancy. About half of the abortions performed by unskilled personnel during the first 4 months of pregnancy are reported to have been done by the respondent herself. Abortions performed by unskilled personnel are most prevalent in the first 4 months of pregnancy. The fewer induced abortions during the fifth month of pregnancy (4.5%) were all performed by a traditional birth attendant.

Table 4 shows the logistic regression results for the probability of having an unsafe abortion among induced abortions (425 cases). Three factors appeared to be significantly related to the probability of having an unsafe abortion: whether the household was poor, the woman's years of education and the woman's indigenous origin. Poorer women are 2.5 times more likely to have an unsafe abortion than richer women (OR = 2.48, 95% CI = 1.09–5.63). In general, there is a negative gradient in the likelihood of having an unsafe abortion across categories of educational attainment. Women with 6–9 years of education are 70% less likely to have an unsafe abortion than women with no years of education (OR = 0.30, 95% CI = 0.11–0.81). Women with more than 13 years

Figure 2 Proportions of abortions performed by unskilled providers by month of pregnancy (sample 425 induced abortions). The height of the bar corresponds to the total proportion of abortions performed by unskilled providers. The different colors show the proportion performed by the respondent herself, a traditional birth attendant, an auxiliary worker, nurse or another person



of education are 93.5% less likely to have an unsafe abortion than women with no years of education (OR = 0.065, 95% CI = 0.01–0.43). However, there was no significant association for the group of women with 10–12 years of education. Women of indigenous origin are 5 times more likely to have an unsafe abortion than non-indigenous women (OR = 5.44, 95% CI = 1.91–15.51). It is interesting to note that the age at the time of abortion, marital status, number of children at the time of the abortion, number of abortions, gestational age and urban/rural residence were not significantly associated with an increased probability of having an unsafe abortion.

We predicted the probability of having an unsafe abortion by the level of deprivation for each state (see the Appendix for a description on the level of deprivation of Mexican states). We found that states with a high deprivation index (poorest states) have a higher probability of having unsafe abortions (around 22%) compared with states with a low deprivation index (richer states, with a probability of around 15%); these differences are statistically significant. At the same time, we found that highly deprived states have the highest proportion of women who have had sex and have never used modern contraceptive methods (27%) or heard about them (9%).

Table 4. Logistic regression results on the probability of having an unsafe abortion among women with an induced abortion (425 women)

Variable name	Odds ratio	95% CI
Economic status		
Non-poor (ref)	1	
Poor	2.479*	1.09–5.63
Education		
<5 years (ref)	1	
6–9 years	0.303*	0.11–0.81
10–12 years	0.854	0.24–3.08
≥13 years	0.065**	0.01–0.43
Age group (at time of abortion)		
15–19 years	2.191	0.73–6.55
20–24 years (ref)	1	
25–34 years	1.483	0.54–4.11
35–55 years	1.243	0.36–4.29
Marital status		
Married (ref)	1	
Single, divorced, widow	0.58	0.21–1.62
No. of children (at time of abortion)		
0 (ref)	1	
1	1.582	0.53–4.71
2	2.198	0.61–7.89
≥3	1.054	0.26–4.33
No. of abortions		
>1 (ref)	1	
1	1.695	0.71–4.03
Months of pregnancy		
1 (ref)	1	
2	1.277	0.48–3.37
3	0.807	0.30–2.19
≥4	1.095	0.38–3.12
Indigenous population		
Not indigenous (ref)	1	
Indigenous	5.444**	1.91–15.51
Area of residence		
Rural area (ref)	1	
Urban area	0.79	0.33–1.88
Sample	425	

*P < 0.05; **P < 0.01; ***P < 0.001.
(ref) = reference group.

Table 5. Probability (and 95% uncertainty intervals) of having an unsafe abortion by indigenous origin, poverty and years of education (probabilities are predicted based on the results of the logistic regression presented in Table 4)

	Indigenous		Not indigenous	
	Poor	Non-poor	Poor	Non-poor
Less than 5 years of education	0.72 (0.49–0.89)	0.57 (0.28–0.83)	0.35 (0.18–0.55)	0.21 (0.09–0.36)
More than 5 years of education	0.47 (0.24–0.72)	0.32 (0.12–0.57)	0.15 (0.08–0.23)	0.08 (0.05–0.12)

The coefficients of the logistic regression model shown in Table 4 were used to estimate probabilities of having an unsafe abortion for subgroups of women in the population. Table 5 shows that, all else being equal, the probability of having an unsafe abortion for poor women with indigenous origin who have less than 5 years of education is 9 times higher compared with non-poor, not indigenous, educated women. The results in Table 5 also imply that among poor indigenous women, those with more than 5 years of education have a lower probability of having an unsafe abortion than those who have less than 5 years of education.

Discussion

This analysis demonstrates that the most significant determinant of having an induced abortion is whether the pregnancy was wanted/mistimed or not and whether the women had three or more children at the time of the abortion. Consistent with our findings Lara et al. found that, in Mexico, women who had unwanted pregnancies are more likely to have induced abortions (Lara et al. 2006a). They also found that growing up in a city and having not yet given birth are significantly and positively associated with the probability of having an induced abortion. However, we found that, as in the USA, women who have more children are more likely to have an induced abortion (Boonstra et al. 2006).

We found that unsafe abortions are significantly associated with lower economic status, a woman's indigenous origin and years of education. This is also consistent with other studies of countries where abortion is illegal. For example, in the USA, when abortion was illegal, poor and minority women were exposed to unsafe procedures while women with financial resources were able to afford safe procedures (Boonstra et al. 2006).

Our results imply that there is poor access to effective family planning methods in Mexico. This might be due to lack of knowledge, misuse or failure of the contraceptive methods, or because of economic and other barriers that impede women from preventing unwanted pregnancies. As a result, and in combination with the fact that abortion is illegal in Mexico, women demand clandestine services. This illegal market of services

contributes to socio-economic inequalities, as well-off women have the ability to seek and pay for safe abortions while disadvantaged women are exposed to unsafe procedures and the long-term consequences related to them (Sousa 2001).

The Mexican government has invested in several efforts to improve maternal services in the past 10 years, including the Program for the Extension of Coverage (PAC), Oportunidades and Fair Start in Life (Arranque parejo en la vida) (Secretaria de Salud 2002a). However, further efforts are required to ensure that all women of reproductive age know of and have access to modern contraceptive methods. This analysis shows that women living in the poorest states have a much higher risk of having an unsafe abortion and at the same time have less knowledge and use of modern contraceptive methods.

In parallel, efforts are required to provide access to safe abortion services to reduce the burden resulting from unsafe procedures. There is an urgent need to eliminate the institutional and legal barriers to provide safe abortion services for all women, and especially for victims of rape (Human Rights Watch 2006). Efforts are required to educate the population on the availability of abortion services as 54% of all Mexicans are unaware that abortion is legal in some circumstances, including rape (Becker et al. 2002). In addition, mid-level health professionals should be trained to provide abortion and post-abortion services (World Health Organization 2003; Chong and Mattar 2006; Warriner et al. 2006). By increasing the number of skilled providers, the barrier imposed by doctors who refuse to provide abortion services would be reduced (Human Rights Watch 2006). In Mexico, among health providers who report that they believe that public health systems should offer abortion services for legal indications, few of them would agree to personally provide the service (Gonzales de Leon and Billings 2001).

In April 2007, induced abortions in Mexico City were legalized within the first 12 weeks of pregnancy (Organo del Gobierno del Distrito Federal 2007). It is therefore likely that the rate of induced abortions will increase in Mexico City, as women will now report abortions that before were hidden because of their illegality. The probability of having an unsafe abortion is likely to decrease as it has been found that in countries where abortion is legal, procedures are more likely to be safe, whereas in countries where it is illegal, procedures are more likely to be performed in unsafe conditions (Jewkes et al. 2005). However, unless women have information on the possibility of having a safe abortion, it is unlikely that poor, uneducated women will immediately profit from the accessibility of safe abortion services. This argument is supported by our findings, which show that a large proportion of women still have never heard about contraception methods. We also found that indigenous women, who are concentrated in rural areas, are more likely to have unsafe abortions. The gains in the safety of the procedures attained in Mexico City will be undermined by unsafe procedures that will still occur in the rest of the country where abortion is still illegal.

As in the USA where liberalization of abortion laws occurred in some states (Boonstra et al. 2006), women seeking an abortion will travel to Mexico City to get a safer procedure. Several consequences will emerge from this: (1) only women with enough financial resources will be able to travel to obtain a safe abortion; (2) the travel from faraway states will delay obtaining the abortion which will therefore increase the risk of complications due to higher gestational weeks; (3) for some women the timing will be determinant as they may pass over the gestational week limit for having a legal abortion; and (4) women who will travel are at higher risk of not receiving proper follow-up and care if a complication arises while returning to their state of residence.

Legalizing abortion is an important step towards reducing the burden of unsafe abortion, but on its own it is not sufficient. As has been shown in India, where abortion is legal, the burden due to unsafe abortion is not reduced unless the provision of services is scaled up to guarantee access to safe abortion for all women (Grimes et al. 2006). Worldwide 48% of all induced abortions are unsafe, in developed regions 92% of abortions are safe, while in developing countries 55% are unsafe (Sedgh et al. 2007).

In this study, we used the WHO classification of unsafe abortion. The limitation of using this classification is that all abortions performed by unskilled providers are defined as unsafe regardless of the procedure. There is increasing evidence that the use of drugs such as misoprostol to perform an abortion is very common in most Latin American countries where abortion is illegal (Misago et al. 1998; IPAS 2005; Miller et al. 2005; Sherris et al. 2005; Lara et al. 2006b). For example, in Brazil, misoprostol was used in 66% of induced abortions (Misago et al. 1998). Several reasons have contributed to increase the use of misoprostol to perform medical abortions: (1) it is known to be an effective self-induced abortifacient and it has been associated with a high reduction in abortion-related mortality (Miller et al. 2005; Harper et al. 2007; Moreno-Ruiz et al. 2007); (2) it is an inexpensive drug; (3) it generally does not require prescription; and (4) it is normally available at the pharmacy (Misago et al. 1998; Miller et al. 2005; Sherris et al. 2005; Lara et al. 2006b). It is therefore likely that many of the self-induced abortions and the abortions performed by a nurse or another person reported in ENADID were induced with misoprostol and misclassified as unsafe according to the WHO classification. Nevertheless, we would like to point out that although the WHO classification is likely to misclassify self-induced abortions as unsafe, further research should be conducted to obtain more detailed information on the use of misoprostol. It has been found that, in Latin America, a large proportion of women, pharmacy staff and providers know neither the recommended dosing regimen of misoprostol to make it an effective abortifacient nor the complications or side effects that could arise from using it (Misago et al. 1998; Miller et al. 2005; Sherris et al. 2005; Lara et al. 2006b).

The limitations of this study should be taken into account when interpreting the findings. ENADID is a survey that was not specifically designed to collect data on abortion,

so only limited information is available. It would be beneficial to also have information on the reasons why an abortion was sought, whether any complications arose from it, and other important factors. Only women who reported ever being pregnant were asked questions on abortions. Women might be reluctant to report having had an abortion in a face-to-face interview because of the illegality of abortion in Mexico. Further, ENADID is a cross-sectional survey that relies on retrospective data, so it is susceptible to recall bias as past abortions may tend to be reported less frequently than recent ones. We tried to mitigate this problem by using the last 5 years of the survey.

In a face-to-face interview, under-reporting of abortions (either induced or spontaneous) is common among women of certain socio-economic characteristics regardless of the legal status of abortion. In the USA, for example, poor, Hispanic and black women are less likely to report an abortion (Jones and Kost 2007). In our study, we analysed data from a face-to-face survey collecting information on pregnancy histories. It is therefore likely that our study suffers from problems of under-reporting. This is likely to affect the magnitude of unsafe abortions among certain groups of the population, such as single women or women in rural areas, categories for which we did not find a significant association with the probability of having an unsafe abortion. Nevertheless, we did find significant and positive associations with the probability of having an unsafe abortion among women who are expected to report fewer abortions, such as poor, indigenous and uneducated women. Although our results do not show that teenage women (in our sample 15–19 years old) are at highest risk for unsafe abortions, we found that 42.5% of women in this age group who have had sex have never used modern contraceptive methods and 8% have never heard of them. Therefore further research should be undertaken focusing on women between 15 and 19 years old regarding their exposure to unwanted pregnancies, practice and use of contraceptive methods, and exposure to unsafe abortion as we believe they are at high risk for unsafe abortions.

Despite the limitations associated with survey data, this analysis has highlighted some critical issues for maternal health and the links with other central factors in development, such as poverty, women's empowerment and education. In countries like Mexico, where abortion is illegal, the practice of abortion is still ongoing, with the consequences of unsafe abortion being disproportionately born by poor, indigenous and less educated women. Continuing efforts to monitor maternal health, and especially abortion and contraceptive use, will be critical in the coming years.

Appendix

Definition of household wealth index

The measure of household wealth was calculated using a hierarchical probit model with a Bayesian adjustment, developed by Ferguson and colleagues and applied previously in other studies (Ferguson et al. 2003; Gakidou et al. 2006; Pongou et al. 2006; Vapattanawong et al. 2007). In this model, wealth is estimated using information on predictors of economic status (such as age and education of the household head, urban/rural residence), and indicators of economic status, primarily consumer goods (such as ownership of televisions, cars, radios) as well as household services (such as source of drinking water or type of toilet). The following 19 indicators of wealth are available in ENADID: type of housing material (roof and wall), type of sanitary facilities, type of water, type of drainage, type of fuel used for cooking, whether the kitchen is a separate room in the house, room density, electricity, television, VCR, mixer, refrigerator, washing machine, stove, heater, car, fixed-line telephone, mobile telephone, and computer. These indicators were used to estimate an index of household wealth and households were subsequently assigned to a wealth quintile. Poor households were defined as belonging to the bottom two quintiles.

Definition of deprivation index

Data on the level of deprivation of Mexican states come from the National Population Council (CONAPO 2006). The level of deprivation is an index estimated for communities and is based on various indicators of economic development including: the proportion of the population living in households without electricity, piped water inside the residence, and sewerage; the proportion living in households with earth floors; the proportion of the adult population who earn less than twice the minimum wage, and the proportion who have not completed primary school; the proportion of the population who live in communities with less than 5000 inhabitants; and, housing density (number of rooms per people). States are classified into five categories ranging from high to low levels of deprivation.

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Chapter 5

Primary health care provision of maternal health services in Brazil

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Abstract

Brazil's health reforms have led to decentralized decision making and great variability in the quantity and quality of health care provision across the country. We estimate the effect of the provision of health resources on the utilization of antenatal care and attended deliveries in health facilities across 5,507 Brazilian municipalities. Health resources are health workers (physicians, nurse professionals, nurse associates and community health workers) and facilities (ambulatory units, hospitals and hospital beds). We add quality indicators in the form of private (versus public) provision, and salary levels. Utilization rises with the provision of facilities and health workers. In poor municipalities utilization also rises with local access to facilities, private rather than public provision of services (private providers can be reimbursed by the government), and highly qualified, but not necessarily highly paid, health workers. Our analysis implies that improving the provision of health resources in poor municipalities to the levels found in rich municipalities would close most of the gap in the coverage of maternal health services.

Introduction

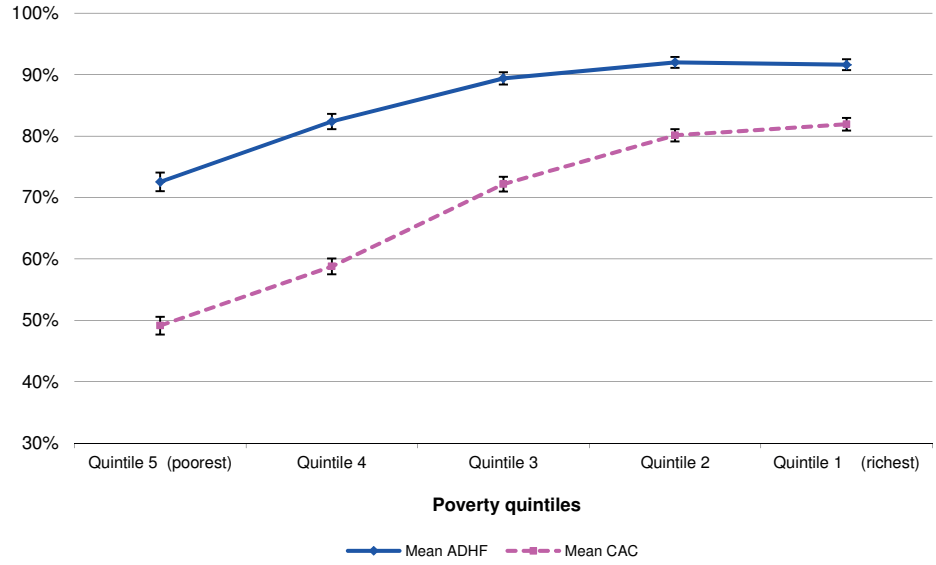
Brazil has undergone a series of major health reforms over the last two decades with an emphasis on the universal provision of health services, particularly primary health care, and large scale decentralization of decision making. The 1988 constitution mandated universal access to health services and established a decentralized health system. The Single Health System (Sistema Unico de Saude –SUS) was established in 1990 which provides access both to public facilities and pays for access to private facilities. While the system is designed to promote universal access there is a great deal of local autonomy in the level of provision, the pay of public sector workers and the reimbursements to the use of private facilities. We investigate the extent to which these reforms have been successful in terms of providing universal access to maternal health services in the form of ante natal care and attended delivery.

There are wide inequalities both between and within countries in access to basic health care services. The poorest 20% of the population in low and middle income countries are less likely to be covered by maternal and child health interventions than their wealthier counterparts (Gwatkin et al. 2007). Both community and household level characteristics have been identified as underlying causes of inequalities in access to health care (Hanson et al. 2003). Shortage and distribution of appropriate qualified staff, lack of equipment and infrastructure including poor accessibility of health services are among the major obstacles of expanding access to priority interventions (Hanson, Ranson, Oliveira-Cruz, & Mills 2003). A number of recent studies have found that countries with higher levels of health workers have better population health as well as better levels of intervention coverage (Anand and Barnighausen 2004;Anand and Barnighausen 2007;Chen et al. 2004) and the same associations are found within countries (Gulliford 2002;Roetzheim et al. 2001;Shi et al. 2003).

While major efforts have been implemented to increase access to health care services for the poor in Brazil it is not clear that these efforts have improved access for the poor (Barros et al. 2005). In the state of Ceara, for example, inequities between rich and poor remained the same even after the implementation of interventions focused on the poorest families (Victora et al. 2000). We examine access to maternal health care in 5,507 municipalities of Brazil in the year 2000. In our data we find that about 92% of women in the richest quintile of municipalities have attended delivery compared with only 73% in the poorest quintile of municipalities (depicted for municipalities grouped by poverty quintiles in Figure 1). About 82% of women in rich neighbourhoods have at least 3 ante natal visits while in those from the poorest neighbourhoods only 49% of women have this level of care.

We use regression analysis to identify the source of these disparities. We find that, in poor communities, the number of health care workers per capita, and the number

Figure 1 Percentage of attended deliveries in health facilities and coverage of antenatal care (+3 visits) by poverty quintiles



of health care facilities, have positive effects on access to maternal health services. The number of health facilities, rather than the size of these facilities, seems to be a key determinant of access for the poor. This may reflect lower transport costs of visiting a health facility when they are more plentiful and less distant. In rich municipalities, access to maternal care depends on the number of hospital beds per capita that are available but not the number of facilities. For poor municipalities utilization depends on having many facilities, even if the total volume of hospital beds does not increase. Having locally available services is what appears to matter in poor neighborhoods.

We also find a positive effect of the quality of the health services provided on the utilization. Utilization is higher, even in poor municipalities, when a higher proportion of the services are in private sector rather than publicly provided, which may reflect higher quality of these services. We also find a positive effect on the average salary of health sector workers in the municipality on utilization rates, though this effect is due to the composition of health work force rather than pay for each category of workers. That is, we find having more doctors, and nurses, rather than community care workers increases utilization, but paying each type of health worker more does not appear to be significantly related with utilization.

These results imply that it is not just the total number of health workers that matter for access to health care. Utilization is higher if there are many, local, primary health care facilities, many high quality health care workers, and more private sector provision. However, public sector salary levels, which might be expected to be linked to the quality

of provision, do not appear to be important. These findings are consistent with the view that women want local high quality care.

Despite the commitment to universal access to health services in Brazil, the decentralization of decision making means that, in practice, poor municipalities have fewer health resources than rich municipalities. While poor municipalities have only slightly fewer health workers per capita than rich municipalities, many of the staff in poor municipalities are community health workers and poor communities have very few doctors. There are 5 times as many doctors per capita in rich municipalities as in poor areas. This lack of provision, relative to richer municipalities, translates into large gaps in access to maternal health services.

We find that differences in the provision of resources explains most of the gap in attended deliveries in health facilities and about a quarter of the gap in the coverage of antenatal care. Our analysis suggests that improving access to human resources and local facilities would have a dramatic impact in the coverage of maternal health interventions among the poor.

Specific background of Brazil

In 1988 the Brazilian Constitution was modified, promising universal coverage (SUS Sistema Unico de Saude- Unified Health System) of health care free of charge. The new constitution states that "Health is a right of all and a duty of the State and shall be guaranteed by means of social and economic policies aimed at reducing the risk of illness and other hazards and at the universal and equal access to actions and services for its promotion, protection and recovery" (1994). In practice, however, there remain major social inequalities.

Over the last decade, responsibility for the administration and provision of public services in health has been decentralized to the level of the municipality – one level below the states. A series of reforms allowed each municipality to design and develop their local health systems according to their needs, as long as they stayed within a set of federal norms. In addition, states and municipalities could use their own resources – physical, financial and human – to augment those provided by the federal government.

Decentralization has had many benefits (Almeida 2002; Barros 2003; Gerschman 2000; Gerschman 2001; Viana and Dal Poz 1998), but the development of health services has been heterogeneous across the municipalities for several reasons: differences in geography, wealth, climate and size. Many of the 5,507 municipalities (in 2000) are very small, while a few are relatively large. In addition, according to Gerschman (Gerschman 2000; Gerschman 2001) the implementation of the decentralization process in some municipalities was marked by clientelistics and patrimonialists procedures – in which people in power provide favours to relatives or clients. These behaviours are still endemic

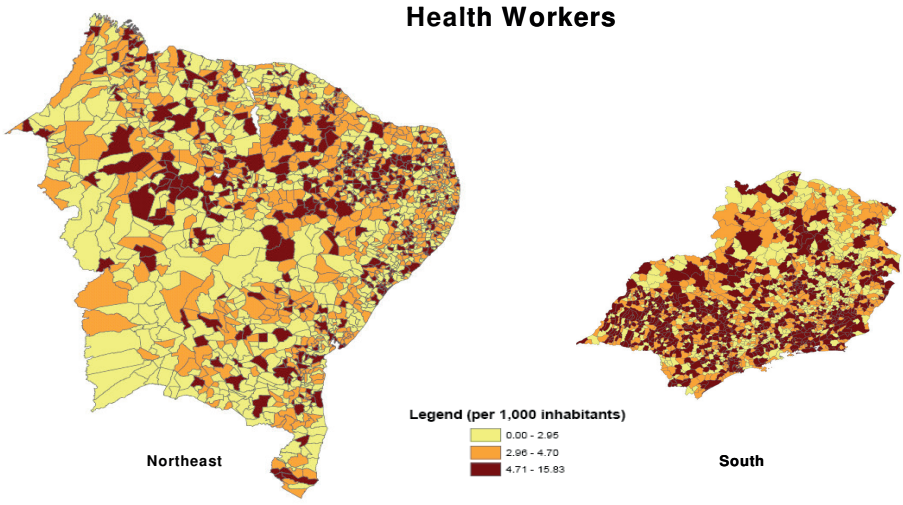
in the Brazilian political and institutional culture, and have influenced the results of the decentralization.

In some municipalities, progress was made through initiatives of the municipal administration, which injected their own resources into the provision of health services, beyond the minimum set by federal guidelines. In others, municipal administrations did not assume responsibility for health activities, which remained largely in the hands of the federal authorities.

In general, however, total funding levels increased with the reforms, which allowed an expansion of services – the most significant being the Health Family Program (PSF) that has to date been implemented in 60% of the municipalities (Peres et al. 2006) and has been linked to the development of a category of community health workers known as Health Communitarian Agents (Viana & Dal Poz 1998). In addition, in some municipalities, more democratic mechanisms for community participation in decision-making were established.

Not surprisingly, we find health workers and health facilities are concentrated in the better-off areas. For example, thirty-eight percent of the municipalities with levels below 2.9 health workers[4] per 1000 inhabitants are concentrated in the Northeast region, which is the poorest and has the highest income inequality (the poorest 20% had 3.5% of the income while the 20% richest had the 62.2% in 2002 (Technical Group for Monitoring the Millennium Development Goals 2004) -see Figure 2). A large number

Figure 2 Geographical distribution of health workers density by municipality in the Northeast and South Regions of Brazil (CENSUS 2000)



[4] The sum of physicians, nurses professionals, nurses associates and community health workers

of the municipalities (39%) with densities over 4.7 health workers per 1000 inhabitants are concentrated in the Southeast and South of the country which are the richest regions.

Data

To analyse the relationship between the availability of resources and the utilization of maternal health services at municipality level, we constructed a cross-sectional dataset that compiles five different sources of information for the 5,507 Brazilian municipalities for the year 2000. Two maternal health interventions were analyzed for each municipality, coverage of antenatal care and attended deliveries in health facilities. We defined our resources or inputs to be labor, represented by the health workers per capita and physical capital represented by the number and size of health facilities.

The first health intervention we examine, the utilization of antenatal care services, is defined as the ratio of the number of live births whose mothers had three or more antenatal care visits over the total live births. The second intervention, attended deliveries in health facilities, is defined as the ratio of number of live births delivered in health facilities over the total number of live births. To construct these indicators we combined two sources of information for the year 2000. Data for the numerators come from the Ministry of Health's Information System on Live Births 2000 (SINASC) (National Agency for Health Surveillance 2000)- and data for the denominator (number of live births) comes from the population Census 2000 (Brazilian Institute of Geography and Statistics (IBGE) 2000).

We consider several health inputs. The first input, is the number of health workers per capita, was obtained from the Census 2000. The census asked people aged 10 years and over, who, during the last week of the reference month, were employed, to state their occupation in which they worked and the industry. Using the Brazilian classification of occupations matching the International Standard Classification of Occupations (ISCO) at fourth digit code level and the International Standard Industry Classification (ISIC), 21 occupations related to health workers and four categories of industry related to the health sector are reported in the Census 2000. Since the interventions analyzed in this study are antenatal care services and attended deliveries in health facilities we used 6 of the 21 categories; due to their direct involvement in the provision of these services (Ministério de Saúde 2006;Unified National Health System (DATASUS) 2000;World Bank 2002).We further combined the six occupations of health workers into four categories: physicians; nurse professionals; nurse associate; and community health workers (see Table 1). We measure health workers in each category in each municipality per 1000 population. We also created a measure of the aggregate density of health workers as the sum of the four categories of health workers per 1000 population.

Table 1 Definitions

Indicator	Definition	Sources
HEALTH INTERVENTIONS		
Proportion of attended deliveries in health facilities	Ratio of the number of live births delivered in health facilities over the maximum number of live births reported by SINASC and CENSUS	CENSUS, SINASC
Proportion of coverage of antenatal care with more than 3 visits	Ratio of the number of live births whose mothers had more than 3 antenatal care visits over the maximum number of live births reported by SINASC and CENSUS	CENSUS, SINASC
INPUTS		
Human capital		
Total health workers per 1000 pop[(b)]	Number of people who reported been a physician, nurse professional, nurse associate or community health worker by occupation over the total population x 1000	CENSUS
Physicians per 1000 pop	Number of people who reported been a physician by occupation (ISCO code 2231) over the total population x 1000	CENSUS
Nurses professionals per 1000 pop	Number of people who reported been a nurse superior level by occupation (ISCO code 2235) over the total population x 1000	CENSUS
Nurses associates per 1000 pop	Number of people who reported been a technicians, auxiliaries of nursing, assistants nursing, practical midwives and similar by occupation (ISCO code 3222 & 5151) over the total population x 1000	CENSUS
Community health workers per 1000 pop	Number of people who reported been a health and environmental agents (ISCO code 3522) over the total population x 1000	CENSUS
Physical capital		
Total health facilities per 1000 pop	Number of public and private outpatient and inpatient facilities (DATASUS and IBGE) over the total population x 1000	CENSUS, DATASUS, IBGE
Ambulatory care facilities per 1000 pop	Number of public and private health facilities with outpatient services (DATASUS and IBGE) over the total population x 1000	CENSUS, DATASUS, IBGE
Hospitals per 1000 pop	Number of public and private hospitals (DATASUS and IBGE) over the total population x 1000	CENSUS, DATASUS, IBGE
Beds (hospital) per 1000 pop	Number of public and private hospital beds (DATASUS and IBGE) over the total population x 1000	CENSUS, DATASUS, IBGE
Private/Public		
Ratio of the number of total private health workers	Number of health workers defined in (b) who reported the private health sector as the industry in which they worked (ISIC code 85012) over the total number of health workers	CENSUS
Ratio of the number of private facilities publicly funded	Number of private facilities publicly funded (SUS funded with private provision) over total private health facilities (sum of IBGE facilities – privately funded – and SUS – publicly funded with private provision)	DATASUS, IBGE

Table 1 (continued)

Indicator	Definition	Sources
Average wage of public health workers	Average wage reported by public health workers (defined in (b) and who reported the public health sector as the industry in which they worked – ISIC code 75, 85011) over the total number of health workers	CENSUS
Relative wage of public health worker	Average wage of public health workers over average wage of public health workers in Brazil	CENSUS
Dummy for private health facilities[(c)]	1 if the municipality has no private health facilities, and 0 otherwise	CENSUS
Dummy for health workers[(d)]	1 if the municipality has no health workers, and 0 otherwise	CENSUS
HETEROGENEITY VARIABLES		
Proportion of population of adult women with less than five years of education	Number of adult women (over 15 years old) with less than 5 years of education over the number of adult women	CENSUS
Proportion of population below the poverty line (R$75)	Proportion of population with monthly family income per capita of less than R$75	IPEADATA
Population density per km^2	Number of people per km^2	CENSUS, IPEADATA
Dummy for population living in urban area	1 if more than 50% of the population is living in urban area (urban municipalities), and 0 otherwise	CENSUS
Number of live births per 1000 pop	Maximum number of live births reported by SINASC and CENSUS over the total population x 1000	CENSUS, SINASC

Note: ISCO code refers to the International Standard Classification of Occupations at fourth digit code level and ISIC code to the International Standard Industry Classification. [(c)] The number of municipalities with no private health workers is 2,450 and [(d)] the number of municipalities with no health workers is 215.

We measure physical capital using three indicators: the density of ambulatory care facilities; the density of hospitals; and the density of hospital beds (per 1000 population). The number of ambulatory care facilities includes all public and private health centers and health posts that provide outpatient services. The number of hospitals includes all public, private and teaching hospitals. We also created a measure of aggregate density of health facilities as the sum of ambulatory units and hospitals per 1000 population.

We also differentiate between the number of public and the number of private facilities. All SUS (Unified Health System) affiliated facilities are publicly funded but the provision of services can be in public or private facilities. Data for SUS facilities were obtained from the Information Department of the Unified National Health System 2000 (DATASUS) under the Ministry of Health, that produces several databases of health indicators at the municipal level. Data for private health capital come from the survey Health Statistics – Medical-Sanitary Assistance – 1999, which is conducted by the Brazilian Institute of Geography and Statistics (IBGE) and supported by the Ministry of Health (Brazilian Institute of Geography and Statistics (IBGE) 1999).

We use data on socioeconomic characteristics of the municipalities as covariates in our analysis to help explain the utilization of maternal health care. Data on socioeconomic characteristics were obtained from two different sources. Using the 2000 Census, we extracted three indicators using sample weights to obtain population estimates for the 5,507 municipalities giving: 1) the proportion of the adult women (over age 15) with less than the average years of education (five years), 2) a dummy variable for municipalities with more than 50% of population living in urban areas, and 3) the region in where the municipality is located.

The Institute of Applied Economic Research (IPEA) compiles and produces time series of socioeconomic indicators such as population, employment, wages, production, consumption and sales for each municipality. From this source we extracted: 1) the proportion of population living below the poverty line (defined as the proportion of population with a monthly family income per capita of less than 75$R)[5] (UNDP Brasil 2004), and 2) the population density per square kilometer.

We arranged the municipalities into quintiles based on each of % of women with less than the average years of schooling, % of population living below the poverty line, and population density per square kilometer. A set of dummy variables were created representing these quintiles. Poor municipalities where defined as municipalities belonging to the top two quintiles (2,202 municipalities) and non-poor otherwise (3,305 municipalities). Table 1 details the definition of the variables used in this analysis and Table 2 the mean, the standard deviation (SD) in the entire sample and the mean by poverty quintiles of all the variables.

Table 2 Descriptive statistics

Definition	Mean All Sample	Std. Dev.	Quintile 1 (richest)	Quintile 2	Quintile 3	Quintile 4	Quintile 5 (poorest)
OUTPUTS/ OUTCOMES							
% of pregnant women with attended deliveries	86%	20%	92%	92%	89%	82%	73%
% of pregnant women cover with more than 3 antenatal visits	68%	24%	82%	80%	72%	59%	49%
INPUTS							
Human capital							
Total health workers per 1000 inhabit	3.96	2.5	4.29	4.33	4.2	3.71	3.24
Physicians per 1000 inhabit	0.29	0.57	0.43	0.43	0.35	0.14	0.08

[5] Which is equivalent to half a minimum wage per capita in august 2000. The universe of population is the total number of people with a permanent address. This indicator is collected from the Census.

Table 2 (continued)

Definition	Mean All Sample	Std. Dev.	Quintile 1 (richest)	Quintile 2	Quintile 3	Quintile 4	Quintile 5 (poorest)
Nurses professionals per 1000 inhabit	0.11	0.31	0.13	0.12	0.13	0.09	0.07
Nurses associates per 1000 inhabit	2.33	1.94	2.83	2.7	2.38	2.01	1.71
Community health workers per 1000 inhabit	1.24	1.28	0.91	1.08	1.33	1.47	1.39
Physical capital							
Total health facilities per 1000 inhabit	0.7	0.43	0.78	0.75	0.69	0.67	0.59
Ambulatory units per 1000 inhabit	0.59	0.38	0.64	0.62	0.59	0.59	0.53
Hospitals per 1000 inhabit	0.1	0.13	0.14	0.13	0.1	0.08	0.07
Beds (hospital) per 1000 inhabit	3.71	4.92	5.12	5	4.09	2.64	1.73
Private/Public							
Ratio of the number of total private health workers	10%	17%	14%	14%	12%	7%	4%
Ratio of the number of private facilities publicly funded	35%	37%	39%	41%	39%	32%	23%
Average wage of public health workers	R$ 453	R$ 474	R$ 542	R$ 536	R$ 508	R$ 378	R$ 299
Relative wage of public health workers	89%	61%	97%	97%	95%	84%	72%
Dummy for private health facilities	0.44	0.5	0.38	0.34	0.36	0.48	0.67
Dummy for health workers	0.04	0.19	0.05	0.04	0.03	0.03	0.04
HETEROGENEITY VARIABLES							
% of adult women with less than five years of education	58%	11%	52%	52%	55%	62%	69%
% of population below the poverty line (R$75)	47%	11%	33%	40%	46%	54%	63%
Population density per km^2	98	533.6	46.9	84.9	204.4	127.7	26.2
% of population living in urban areas	59%	23%	70%	68%	62%	54%	40%
Number of life births per 1000 inhabitants	19	5	16.4	17.5	19.5	21	22.7

Methodology

We investigate the relationship between the supply of health workers and health facilities and access to antenatal care and attended deliveries in health facilities using a

production function approach.

We modeled the production of the *a*-th health intervention as a function of a vector of inputs X_i for the *i*-th municipality and the socio economic characteristics, Z_i, of the municipality. The X_i vector of inputs is composed of the quantity of health human resources and health physical capital together with some quality indicators. We assume

$$Y_{ai} = f(X_i, \mathbf{Z_i}) \quad \text{where } a=1,2 \text{ and } i = 1, \ldots, n \tag{1}$$

where Y_{ai} denotes the utilization of the *a*-th health intervention for the *i*-th municipality. The $\mathbf{Z_i}$ vector of variables is composed of the proportion of the population living below the poverty line pl_i, the number of live births per 1000 inhabitants lb_i, the proportion of the adult women with less than five years of education ed_i, the population density per km^2 pop_i, the proportion of the population living in urban areas urb_i and the region where the municipalities are located reg_i.

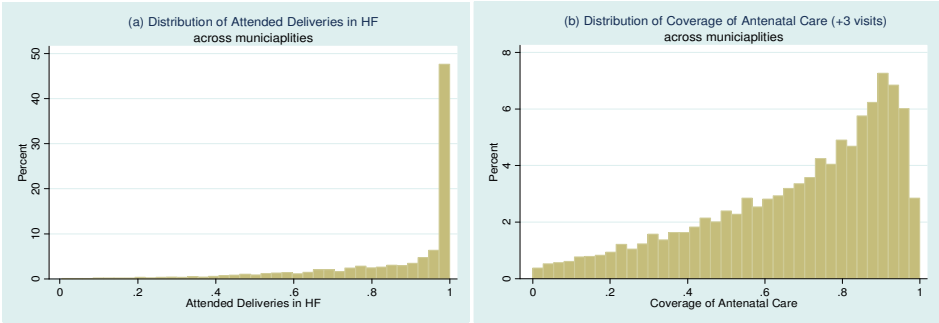
In the production function of equation (1) we wish to measure the relative contribution of the health workers and health facilities to access to health care. Health workers are disaggregated by four types of health workers and health facilities by two types of facilities. Then the disaggregate production function is:

$$y_{ai} = f(P_i, NP_i, NA_i, CHW_i, AU_i, Hos_i, B_i, \mathbf{Z_i}) \tag{2}$$

where we have four measures of health human resources, P_i is physicians, NP_i nurses professional, NA_i nurses associates, CHW_i community health workers, and three measures of physical capital, AU_i ambulatory units, Hos_i hospitals and B_i hospital beds. All variables are measured per 1000 population. We also use data on whether the labor and capital inputs are in the private or public sectors to see if this makes a difference to service utilization.

The distribution of attended deliveries in health facilities across municipalities and the distribution of coverage of antenatal care are shown in Figure 3 a. and b. respectively. The histograms show that the two health interventions are skewed to the right. Almost 50% of the municipalities have all deliveries performed in health facilities, whereas though the distribution is right skewed only 3% of the municipalities have all live births covered with more than three antenatal care visits. Since the maximum level of coverage (100%) for delivers in a health facility is a true value there is no problem with observing the variables. This implies that the y_a observed at 100% are not censored or truncated but rather a corner solution. However, the model recommended in the literature to deal with such corner solutions is the censored regression model (the Tobit model, (Wooldridge 2002)). We use this model for both of our variables in our analysis.

Figure 3 Distribution of maternal health interventions across municipalities



The structural equation in the Tobit model is:

$$y^*_{ai} = \mathbf{x_i}\boldsymbol{\beta_a} + \mathbf{Z_i}\boldsymbol{\delta_a} + \varepsilon_{ai} \tag{4}$$

where $\varepsilon_{ai}|\mathbf{x_i} \sim$ Normal $(0, \sigma^2)$, y^*_{ai} is a latent variable observed for values less than τ and censored otherwise. The observed y_{ai} is defined by the following measurement equation

$$y_{ai} = \begin{cases} y^*_{ai} = \mathbf{x_i}\boldsymbol{\beta_a} + \mathbf{Z_i}\boldsymbol{\delta_a} + \varepsilon_{ai} & \text{if } y^*_{ai} < \tau \\ \tau_y & \text{if } y^*_{ai} \geq \tau \end{cases} \quad \text{where } \tau = 1 \tag{5}$$

Then the recorded health is $y_{ai} = \min(1, y^*_{ai})$. In Tobit regression model for corner solution applications the interest centers on probabilities or expectations involving y. Hence the focus is in $E(y|\boldsymbol{x})$ or $E(y|\boldsymbol{x}, y<\tau)$ which are non linear in $\mathbf{x_i}\boldsymbol{\beta_a}$[6].

We investigate a policy of targeting the municipalities that have less than 100% coverage with increased inputs. Thus we are interested in the partial effect of *x's* on the conditional expectation of uncensored observations $E(y|\boldsymbol{x}, y<1)$. If we regard the error terms as fixed, the marginal effect of a small change in inputs will be exactly the estimated coefficient β. However, suppose that after we carry out the policy we get new draws of the random error terms ε_{ai}. Some of these draws may take the municipality over the 100% coverage boundary making the actual outcome smaller than expected. Some of the policy intervention will be "wasted" on municipalities that would in any case go to 100% coverage for other reasons.

If the error terms are taken to be municipality specific unobserved factors that are constant over time we could regard them as fixed and a policy of a unit increase in inputs, targeted to the municipalities that are below complete coverage, will increase

[6] In censored models changes in the latent y^* are of primary interest. However this is not the case for corner solution applications because y^* is simply an artificial construct.

outcomes by the estimated coefficient β. However, if the error terms represent random variation that occurs each period we have to take into account the leakage of the policy to municipalities that would have achieved complete coverage in any case. We do not know how much of our error term represented fixed but unobserved inter-municipal heterogeneity and how much is due to random shocks within each municipality that vary over time. We focus on the effect assuming that the error terms are not fixed. This gives us a lower bound for the effect of the policy; if the errors are actually fixed the policy effects will be larger than our predictions.

The marginal effect product of a policy to change inputs for the uncensored observations, given a new random draw of the error term after the policy intervention, is:

$$\frac{\partial(y|\mathbf{x},\, y<\tau)_a}{\partial x_{ka}} = \beta_{ka} + \frac{\partial(\varepsilon|\mathbf{x},\, y<\tau)_a}{\partial x_{ka}} = \beta_{ka}\left\{1-\lambda_a(\alpha)\left[\frac{\mathbf{x}\boldsymbol{\beta}_\mathbf{a}+\mathbf{Z}\boldsymbol{\delta}_\mathbf{a}}{\sigma_a}+\lambda_a(\alpha)\right]\right\} \qquad (6)$$

where $\lambda_a(\alpha) = -\left[\dfrac{\phi_a\left(\tau-\dfrac{\mathbf{x}\boldsymbol{\beta}_\mathbf{a}+\mathbf{Z}\boldsymbol{\delta}_\mathbf{a}}{\sigma_a}\right)}{\Phi_a\left(\tau-\dfrac{\mathbf{x}\boldsymbol{\beta}_\mathbf{a}+\mathbf{Z}\boldsymbol{\delta}_\mathbf{a}}{\sigma_a}\right)}\right]$ is the inverse Mills ratio when $y^*_{ai} < \tau$

As well as estimating the pooled model, we investigate if the factors that determine utilization differ in poor and non poor municipalities. We begin by estimating equations (1) and (2) for the entire sample and then estimating the same equations for poor and non poor municipalities separately. Estimates were produced using robust standard errors to adjust for the possible presence of heteroscedasticity. Seemingly unrelated tobit models are estimated for our two outcome variables where we estimated both regressions simultaneously while allowing for the possibility of correlated errors (for example due to the presence of hidden factors that affect utilization of both ante natal care and attended delivery). In seemingly unrelated OLS regressions there is no efficiency gain if the explanatory variables in the two regressions are the same however, with seemingly unrelated tobit regressions there is an efficiency gain (Huang et al. 1987). The production function results, computed using STATA 9, are presented in the following section.

Results

Table 3 show the results of the production functions of attended deliveries and coverage of antenatal care services for poor (2,202) and non-poor municipalities (3,305). In this table we report results where the human resources are aggregated in the total number of health workers and the number of health facilities. The parameters of each regression were estimated using censored Tobit model.

Table 3. General Production Function Estimation for Attended Deliveries in HF and Coverage of Antenatal care (+3 visits)

	Attended Deliveries in HF ♣			Coverage of Antenatal Care (+3 visits) ♣		
Variable name	Column 1	Column 2 Poor	Column 3 Non-Poor	Column 4	Column 5 Poor	Column 6 Non-Poor
INPUTS						
Labor						
Total health workers per 1000 pop	0.005***	0.009***	0.002	0.003	0.010***	-0.000
	(3.488)	(3.319)	(1.523)	(1.729)	(4.147)	(-0.173)
Capital						
Total health facilities per 1000 pop	0.043***	0.090***	-0.000	0.058***	0.099***	0.022*
	(4.757)	(6.074)	(-0.001)	(7.855)	(7.747)	(2.534)
Beds (hospital) per 1000 pop	0.001	0.002	0.001	-0.000	-0.001	0.001
	(0.922)	(0.769)	(1.449)	(-0.520)	(-0.823)	(1.385)
Private/Public						
Ratio of the number of private health workers	0.072***	0.119**	0.059**	0.052***	0.098*	0.038**
	(3.864)	(2.767)	(3.042)	(3.658)	(2.551)	(2.657)
Ratio of the number of private facilities publicly funded	0.002	0.030	-0.022	0.018	0.076***	-0.025
	(0.161)	(1.191)	(-1.280)	(1.442)	(3.341)	(-1.818)
Dummy for priv. HF (1 no private health facilities, 0 otherwise)	-0.035**	-0.007	-0.059***	-0.024*	0.017	-0.054***
	(-2.840)	(-0.320)	(-4.066)	(-2.396)	(0.957)	(-4.643)
Average wage of public health workers	0.019**	0.045**	0.010	0.014**	0.027*	0.010
	(2.840)	(3.006)	(1.428)	(2.750)	(2.142)	(1.715)
Dummy for HW (1 no health workers, 0 otherwise)	-0.015	0.022	-0.043	-0.003	0.032	-0.032
	(-0.792)	(0.708)	(-1.837)	(-0.169)	(1.129)	(-1.561)
HETEROGENEITY VARIABLES						
% of population below the poverty line (R$75)[a]						
Quintile 1 (richest)	0.008		0.002	0.023**		0.020*
	(0.792)		(0.255)	(2.897)		(2.524)
Quintile 2	0.004		0.000	0.017*		0.013
	(0.474)		(0.016)	(2.333)		(1.853)
Quintile 3	-0.019	0.017		-0.039***	0.008	
	(-1.934)	(1.582)		(-4.363)	(0.854)	
Quintile 4	-0.046***			-0.052***		
	(-3.780)			(-4.712)		
Region[b]						
Region N	-0.030*	-0.063***	0.072**	-0.008	-0.035*	0.082***
	(-2.020)	(-3.369)	(3.096)	(-0.645)	(-2.296)	(4.177)
Region CW	0.040**	0.041	0.064***	0.097***	0.097***	0.132***
	(2.647)	(1.367)	(3.515)	(7.740)	(4.257)	(7.997)

Table 3 (continued)

Variable name	Attended Deliveries in HF ♣			Coverage of Antenatal Care (+3 visits) ♣		
	Column 1	Column 2 Poor	Column 3 Non-Poor	Column 4	Column 5 Poor	Column 6 Non-Poor
Region S	0.058***	0.139***	0.087***	0.106***	0.163***	0.158***
	(5.141)	(5.718)	(6.159)	(10.843)	(7.408)	(11.638)
Region SE	-0.038***	-0.068***	0.006	0.029**	-0.024	0.085***
	(-3.540)	(-3.687)	(0.406)	(3.017)	(-1.484)	(6.257)
Number of live births per 1000 pop[c]						
Quartile 1 (less live births)	0.114***	0.078***	0.126***	0.125***	0.124***	0.123***
	(11.073)	(4.127)	(9.282)	(14.318)	(7.690)	(10.303)
Quartile 2	0.079***	0.082***	0.085***	0.102***	0.110***	0.096***
	(8.633)	(5.959)	(6.544)	(12.508)	(8.813)	(8.285)
Quartile 3	0.052***	0.056***	0.054***	0.074***	0.072***	0.073***
	(6.036)	(4.823)	(4.269)	(9.563)	(6.862)	(6.438)
% of adult women with less than five years of education[d]						
Quintile 1 (more educated women)	0.060***	0.048	0.073***	0.113***	0.134***	0.107***
	(4.336)	(1.802)	(3.666)	(9.500)	(5.311)	(6.118)
Quintile 2	0.056***	0.039	0.062**	0.095***	0.082***	0.092***
	(4.448)	(1.814)	(3.250)	(8.679)	(4.234)	(5.436)
Quintile 3	0.055***	0.034*	0.060**	0.076***	0.063***	0.076***
	(4.924)	(2.206)	(3.246)	(7.667)	(4.616)	(4.646)
Quintile 4	0.030**	0.018	0.027	0.045***	0.034**	0.045**
	(2.913)	(1.450)	(1.360)	(4.902)	(3.072)	(2.609)
Population density[c]						
Quintile 2	0.069***	0.066***	0.060***	0.065***	0.083***	0.042***
	(6.145)	(3.952)	(4.156)	(7.020)	(5.858)	(3.502)
Quintile 3	0.104***	0.092***	0.095***	0.100***	0.105***	0.082***
	(9.005)	(5.149)	(6.586)	(10.580)	(6.935)	(6.888)
Quintile 4	0.117***	0.127***	0.092***	0.114***	0.125***	0.090***
	(10.131)	(7.140)	(6.373)	(11.968)	(8.146)	(7.438)
Quintile 5 (more population density)	0.119***	0.158***	0.083***	0.131***	0.152***	0.105***
	(9.832)	(8.598)	(5.486)	(12.974)	(9.789)	(8.119)
% of population living in urban areas						
Dummy urban (1 for > 50% of the population living in urban area; 0 otherwise)	0.081***	0.093***	0.062***	0.036***	0.036***	0.037***
	(10.096)	(8.067)	(5.713)	(5.204)	(3.463)	(4.194)
_cons	0.616***	0.499***	0.662***	0.354***	0.212***	0.398***
	(28.552)	(17.462)	(22.775)	(19.417)	(9.004)	(15.342)

Table 3 (continued)

	Attended Deliveries in HF ♣			Coverage of Antenatal Care (+3 visits) ♣		
Variable name	Column 1	Column 2 Poor	Column 3 Non-Poor	Column 4	Column 5 Poor	Column 6 Non-Poor
lnsigma	-1.585***	-1.514***	-1.700***	-1.720***	-1.622***	-1.832***
	(-111.155)	(-86.613)	(-70.955)	(-148.248)	(-122.073)	(-95.038)
sigma	0.205	0.220	0.183	0.179	0.198	0.160
ll	-246.020	-11.310	-129.769	1615.951	447.051	1314.869
chi2	1984.536	828.657	586.517	5163.558	1205.563	1231.104
Sample	5507	2202	3305	5507	2202	3305

Note 1: statistical significance with a * p<0.05; ** p<0.01; *** p<0.001 and t-values in parenthesis. Note2: The reference group in a is Quintile 5 (poorest quintile), in b is Region NE, in c is Quintile 4 (more live births), in d is Quintile 5 (less educated women) and in e is Quintile 1 (less population density). Note 3: ♣ poor refers to municipalities in quintile 4 and 5 of % of population below the poverty line, and non-poor to municipalities in quintile 3, 2 and 1.

The magnitude of the effect of the inputs in censored tobit models with corner solution variables cannot be interpreted directly from the coefficients when we are near the maximum, however, the estimated coefficients are closing the size of the effect in municipalities that are well below 100% coverage.

The first three columns of table 3 present the results of the aggregate production function of attended deliveries in health facilities and the subsequent three columns present the results of the production process of coverage of antenatal care.

In column 1 of table 3 we find that after controlling for municipalities' socioeconomic characteristics, both the number of workers and number of facilities are positively and significantly related to coverage of attended deliveries; while hospital beds do not have a significant impact.

When we separated the sample by poor and non poor municipalities, in columns 2 and 3, we find that in poor municipalities total health workers and total health facilities have a positive and strong relation with coverage attended delivers. In rich municipalities, people can more easily afford transport costs and the level of utilization is not closely tied to the level of local provision. On the other hand, in poor municipalities the problem of transport costs may mean that what is important is having a high number of facilities and human resources locally, which means more chance of having one close by.

We also include some additional variables to investigate the effect of the "quality" of the services provided. We find utilization is higher when there is a high ratio of private to public health workers, even in poor areas. Public funding of private health facilities does not seem to have an effect. We do however find a positive effect of the average wage of health workers (which could proxy their quality) on utilization levels in poor

areas. We assume that the effect of provision on utilization are linear but we include two dummy variables to allow for discontinuities in response when a municipality has no private health facilities and when it has no health workers. We find that the complete absence of private health facilities reduces utilization in rich municipalities.

All the dummies included in the utilization regressions to control for heterogeneity across municipalities in socio-economic status are significant and have the expected signs. Better off municipalities have more coverage than municipalities in the fifth quintile (poorer municipalities -category of reference-). Municipalities located in the Northeast region (which is the region with the lowest GDP per capita -category of reference-); have less coverage than municipalities located in the other regions, except for municipalities located in the North (which is also a very poor region) and the Southeast, which has an unexpected negative sign. Municipalities with less live births per 1,000 inhabitants have more coverage than municipalities in the fourth quartile (with more live births per 1,000 inhabitants -category of reference-). Municipalities where adult women are more educated have more coverage than municipalities in the fifth quintile (where adult women are less educated -category of reference-). Municipalities with more population density per km2 have more coverage than municipalities in the first quintile (with less population density per km2 -category of reference-). And finally, urban municipalities have more coverage than rural municipalities.

The final three columns of table 3 repeat the analysis for coverage of antenatal care. The results here are similar. Physical and human resources matter for utilization in poor municipalities. They appear to matter less in rich municipalities – though the number of facilities does have some effect. Private provision appears to increases access even in poor municipalities and high wages for health workers is associated with higher levels of utilization.

Table 3 reported results where we aggregated human resources and physical capital. The results of a more disaggregated production process are presented in Table 4. We split the health labor force into physicians, nurse professionals, nurse associates and community health workers. Facilities are divided into ambulatory units and hospitals and we keep the number of hospital beds. We find that labor inputs matter in poor municipalities. It tends to be high quality labor in the form of doctors and nurses that matters rather than community health workers. The poor respond to the number of facilities while the rich are more responsive to the overall volume of resources (hospital beds). Private provision tends to increase utilization, particularly for the poor. One difference from table 3 is that in this specification the average wage paid to health workers is not significantly related to utilization. The effect of high pay in table 3 appears to come from the effect of having more highly qualified staff, rather than paying staff with similar qualifications higher rates than other municipalities.

Table 4 Disaggregated Production Function Estimation for Attended Deliveries in HF and Coverage of Antenatal care (+3 visits)

	Attended Deliveries in HF ♣			Coverage of Antenatal Care (+3 visits) ♣		
Variable name	Column 1	Column 2 Poor	Column 3 Non-Poor	Column 4	Column 5 Poor	Column 6 Non-Poor
INPUTS						
Labor						
Physicians per 1000 pop	0.007	0.055***	0.001	0.011*	0.040***	0.006
	(1.304)	(3.848)	(0.270)	(2.447)	(3.480)	(1.425)
Nurses professionals per 1000 pop	0.010	0.056**	-0.006	0.028**	0.064**	0.016
	(0.786)	(2.815)	(-0.442)	(2.618)	(3.023)	(1.356)
Nurses associates per 1000 pop	0.005**	0.011**	0.002	0.001	0.010**	-0.003
	(2.781)	(2.756)	(0.822)	(0.513)	(3.191)	(-1.324)
Community health workers per 1000 pop	0.004	0.001	0.005	0.003	0.004	0.004
	(1.448)	(0.360)	(1.769)	(1.598)	(1.053)	(1.597)
Capital						
Ambulatory units (outpatient services) per 1000 pop	0.040***	0.071***	0.005	0.058***	0.085***	0.026**
	(4.008)	(4.494)	(0.394)	(7.427)	(6.248)	(2.889)
Hospitals per 1000 pop	0.081*	0.374***	-0.050	0.057	0.288***	-0.031
	(2.154)	(4.640)	(-1.245)	(1.897)	(4.343)	(-0.948)
Beds (hospital) per 1000 pop	0.000	-0.004	0.002*	-0.000	-0.006**	0.002**
	(0.203)	(-1.786)	(2.147)	(-0.426)	(-2.605)	(2.580)
Private/Public						
Ratio of the number of private health workers	0.070***	0.094*	0.062**	0.047**	0.079*	0.037*
	(3.609)	(2.174)	(3.083)	(3.199)	(2.068)	(2.520)
Ratio of the number of private facilities publicly funded	0.003	0.033	-0.024	0.019	0.077***	-0.026
	(0.223)	(1.320)	(-1.391)	(1.497)	(3.425)	(-1.869)
Dummy for priv. HF (1 no private health facilities, 0 otherwise)	-0.034**	-0.004	-0.064***	-0.024*	0.018	-0.057***
	(-2.693)	(-0.200)	(-4.341)	(-2.254)	(0.998)	(-4.629)
Relative wage of public health workers	0.009	0.010	0.006	0.003	-0.001	0.004
	(1.586)	(0.967)	(0.940)	(0.807)	(-0.093)	(1.010)
Dummy for HW (1 no health workers, 0 otherwise)	-0.014	0.016	-0.041	-0.006	0.023	-0.032
	(-0.711)	(0.507)	(-1.706)	(-0.347)	(0.780)	(-1.567)
HETEROGENEITY VARIABLES						
% of population below the poverty line (R$75)[a]						
Quintile 1 (richest)	0.006		0.004	0.023**		0.023**
	(0.647)		(0.404)	(2.997)		(2.879)
Quintile 2	0.003		0.001	0.017*		0.015*
	(0.376)		(0.092)	(2.387)		(2.067)

Table 4 (continued)

Variable name	Attended Deliveries in HF ♣			Coverage of Antenatal Care (+3 visits) ♣		
	Column 1	Column 2 Poor	Column 3 Non-Poor	Column 4	Column 5 Poor	Column 6 Non-Poor
Quintile 3	-0.020	0.021		-0.039***	0.011	
	(-1.952)	(1.919)		(-4.349)	(1.173)	
Quintile 4	-0.047***			-0.052***		
	(-3.819)			(-4.729)		
Region[b]						
Region N	-0.028	-0.060**	0.070**	-0.008	-0.032*	0.078***
	(-1.920)	(-3.182)	(2.992)	(-0.664)	(-2.097)	(4.008)
Region CW	0.039*	0.037	0.066***	0.098***	0.096***	0.135***
	(2.547)	(1.232)	(3.544)	(7.752)	(4.212)	(8.080)
Region S	0.058***	0.148***	0.087***	0.105***	0.170***	0.158***
	(5.137)	(6.052)	(6.097)	(10.767)	(7.641)	(11.642)
Region SE	-0.036***	-0.063***	0.006	0.029**	-0.020	0.086***
	(-3.307)	(-3.386)	(0.419)	(3.059)	(-1.242)	(6.263)
Number of live births per 1000 pop[c]						
Quartile 1 (less live births)	0.114***	0.076***	0.128***	0.125***	0.123***	0.124***
	(11.070)	(3.970)	(9.408)	(14.336)	(7.535)	(10.435)
Quartile 2	0.080***	0.080***	0.085***	0.102***	0.108***	0.096***
	(8.687)	(5.789)	(6.594)	(12.568)	(8.788)	(8.348)
Quartile 3	0.052***	0.055***	0.054***	0.074***	0.071***	0.073***
	(6.052)	(4.770)	(4.264)	(9.623)	(6.819)	(6.504)
% of adult women with less than five years of education[d]						
Quintile 1 (more educated women)	0.060***	0.040	0.073***	0.112***	0.128***	0.105***
	(4.338)	(1.500)	(3.690)	(9.379)	(5.034)	(6.027)
Quintile 2	0.056***	0.032	0.063**	0.095***	0.078***	0.091***
	(4.390)	(1.496)	(3.260)	(8.673)	(4.053)	(5.397)
Quintile 3	0.055***	0.030*	0.060**	0.076***	0.060***	0.076***
	(4.859)	(1.973)	(3.225)	(7.666)	(4.410)	(4.618)
Quintile 4	0.030**	0.015	0.027	0.045***	0.032**	0.045**
	(2.900)	(1.195)	(1.395)	(4.924)	(2.919)	(2.598)
Population density[c]						
Quintile 2	0.069***	0.067***	0.060***	0.066***	0.084***	0.044***
	(6.202)	(4.031)	(4.189)	(7.139)	(5.895)	(3.660)
Quintile 3	0.104***	0.093***	0.096***	0.100***	0.106***	0.084***
	(9.012)	(5.247)	(6.632)	(10.656)	(7.043)	(7.041)
Quintile 4	0.118***	0.127***	0.092***	0.115***	0.124***	0.090***
	(10.188)	(7.175)	(6.321)	(12.021)	(8.131)	(7.457)

Table 4 (continued)

	Attended Deliveries in HF ♣			Coverage of Antenatal Care (+3 visits) ♣		
Variable name	Column 1	Column 2 Poor	Column 3 Non-Poor	Column 4	Column 5 Poor	Column 6 Non-Poor
Quintile 5 (more population density)	0.121***	0.161***	0.082***	0.131***	0.154***	0.104***
	(9.932)	(8.801)	(5.397)	(12.908)	(9.957)	(7.985)
% of population living in urban areas						
Dummy urban (1 for > 50% of the population living in urban area; 0 otherwise)	0.080***	0.092***	0.062***	0.036***	0.034***	0.038***
	(10.039)	(8.022)	(5.760)	(5.216)	(3.348)	(4.287)
_cons	0.614***	0.509***	0.661***	0.355***	0.225***	0.397***
	(27.942)	(17.174)	(22.708)	(19.225)	(9.151)	(15.264)
lnsigma	-1.585***	-1.520***	-1.701***	-1.721***	-1.628***	-1.834***
	(-111.120)	(-87.679)	(-71.143)	(-148.860)	(-121.851)	(-96.379)
sigma	0.205	0.219	0.183	0.179	0.196	0.160
ll	-247.450	2.053	-128.313	1620.261	459.737	1321.898
chi2	2002.988	855.796	598.760	5226.201	1243.293	1250.169
Sample	5507	2202	3305	5507	2202	3305

Note 1: statistical significance with a * p<0.05; ** p<0.01; *** p<0.001 and t-values in parenthesis. Note2: The reference group in a is Quintile 5 (poorest quintile), in b is Region NE, in c is Quintile 4 (more live births), in d is Quintile 5 (less educated women) and in e is Quintile 1 (less population density). Note 3: ♣ poor refers to municipalities in quintile 4 and 5 of % of population below the poverty line, and non-poor to municipalities in quintile 3, 2 and 1.

As in the general production process in Table 3, all dummies included in the disaggregated production process of health interventions to control for heterogeneity across municipalities are significant and have the expected signs.

Table 5 reports test of the hypotheses the effects of our explanatory variables on utilization are the same in rich and poor municipalities. In general, we found that the various health inputs are differently related to the health of poor and non-poor municipalities. Poor areas tend to be more significantly responsive to the number of health workers and facilities provided than rich areas. Poor areas are generally also more responsive to the ratio of provision that is from the private sector, though the rich are affected discontinuously if there is a complete absence of private provision.

For policy implications we are interested in the marginal effects of the inputs in the sample of municipalities who have not attained the maximum level of intervention. We estimate partial effects on the conditional expectation of coverage of antenatal care and attended deliveries in health facilities when we increase resources and initially have less than 100% utilization using equation (6). Table 6 reports the effect in poor com-

Table 5 Hypothesis test for cross-model equality of the coefficients

Hypothesis tested for differences in coefficients in different samples (coefficient poor = coefficient non poor)	Attended Deliveries in HF		Coverage of Antenatal Care (+3 visits)	
General Model	chi2	Prob > chi2	chi2	Prob > chi2
Total health workers	4.57	0.032	10.57	0.001
Total health facilities	24.43	0.000	24.7	0.000
Beds	0.05	0.825	1.51	0.219
Private/Public				
Ratio of the number of private health workers	1.62	0.203	2.14	0.143
Ratio of the number of private facilities publicly funded	2.92	0.087	14.44	0.000
Dummy for priv. HF (1 no private health facilities, 0 otherwise)	4.17	0.041	10.99	0.000
Average wage of public health workers	4.60	0.032	1.6	0.205
Dummy for HW (1 no health workers, 0 otherwise)	2.79	0.095	3.33	0.681
Disaggregated Model				
Labor				
Physicians	12.38	0.000	7.39	0.006
Nurses professionals	6.67	0.009	4.01	0.451
Nurses associates	4.01	0.045	11.10	0.000
Community health workers	0.57	0.448	0.01	0.922
Capital				
Ambulatory units	11.22	0.000	12.87	0.000
Hospitals	22.18	0.000	18.56	0.000
Beds	5.82	0.015	10.56	0.001
Private/Public				
Ratio of the number of private health workers	0.47	0.494	1.05	0.304
Ratio of the number of private facilities publicly funded	3.53	0.060	15.19	0.000
Dummy for priv. HF (1 no private health facilities, 0 otherwise)	5.48	0.019	11.68	0.000
Relative wage of public health workers	0.12	0.733	0.25	0.618
Dummy for HW (1 no health workers, 0 otherwise)	2.05	0.1525	2.36	0.124

munities of raising their provision of health sector workers and facilities to the average provision level found in rich communities.

An increase in the number of physicians in poor municipalities to the average level found in rich municipalities would increase the proportion of coverage of attended deliveries by about 4.8%, and the expected proportion of coverage of antenatal care by about 2.7%. Likewise increases in the number of nurses to rich municipality levels would increase utilization rates in poor areas. Rich municipalities actually have fewer

Table 6 Effects of raising the inputs factors in poor municipalities to the average level found in rich municipalities

	Effects in poor municipalities*		Mean health resources		
Variable name	Coverage of attended deliveries in HF	Coverage of antenatal care	Poor	Non-poor	Difference
INPUTS					
Labor					
Physicians per 1000 inhabit	4.8%	2.7%	0.11	0.40	0.29
Nurses professionals per 1000 inhabit	0.9%	0.7%	0.08	0.13	0.05
Nurses associates per 1000 inhabit	2.5%	1.9%	1.86	2.64	0.77
Community health workers per 1000 inhabit	-0.1%	-0.3%	1.43	1.11	-0.32
Capital					
Ambulatory units (outpatient services) per 1000 inhabit	1.3%	1.2%	0.56	0.62	0.06
Hospitals per 1000 inhabit	5.5%	3.3%	0.07	0.12	0.05
Beds (hospital) per 1000 inhabit	-3.4%	-3.3%	2.18	4.73	2.55
Private/Public					
Ratio of the number of private health workers	2.3%	1.5%	0.05	0.13	0.08
Ratio of the number of private facilities publicly funded	1.2%	2.1%	0.28	0.39	0.12
Dummy for priv HF (1 no private health facilities, 0 otherwise)	0.3%	-0.9%	0.57	0.36	-0.22
Relative wage of public health workers	0.6%	0.0%	0.78	0.96	0.18
Dummy for HW (1 no health workers, 0 otherwise)	0.0%	0.0%	0.04	0.04	0.00
Total partial effects of labor and capital inputs	11.5%	6.2%			
Current gap between coverage of poor and non poor municipalities	14%	24%			
Remaining gap between the coverage of poor and non poor municipalities after the sum of partial effects of labor and capital inputs	2.5%	17.8%			

* Note: The results of raising utilization in poor municipalities by increasing the resources to the level found in rich municipalities

community health workers than poor municipalities so adjusting to this "gap" actually leads to a decrease in utilization.

The largest impact on utilization would come from increasing the number of hospitals in poor municipalities to the level found in rich areas, though the effect of hospital beds is estimated to be negative. We also find positive effect of increasing ambulatory facilities. Increasing the ratio of services coming from the private sector in poor areas to match the ratios found in rich municipalities would also increase utilization rates.

At the bottom of table 6 we estimate the total effect on utilization in poor municipalities of closing the gap in the provision between rich and poor areas. The gap would decrease from 14% to 2.5% in attended deliveries and from 24% to 17.8% in the coverage of antenatal care.

Conclusions

In this study we investigated the relationship between the provision of health workers and health infrastructure and the utilization of antenatal care and attended deliveries in health facilities in Brazil. In general, we found that the provision of health workers and health facilities are particularly important for utilization in poor municipalities. We also found the private provision increases utilization, even in poor municipalities, and that having highly qualified health workers improves utilization, suggesting a response to the quality as well as the volume of provision.

The interventions studied in this analysis are related to pregnancy, child birth and the new born which are directly linked to the attainment of MDG4 infant mortality and MDG5 maternal mortality. Thus special attention to a more equitable health system is required to allocate the resources in order to improve the health of poor population in Brazil and reach the MDGs by 2015. Our results imply that improving access to human resources and local facilities would have a large impact in the coverage of maternal health interventions in poor municipalities in Brazil.

The Commission on Macroeconomics and Health suggested that access to the majority of the interventions that are effective against the primary causes of mortality among the poor could be widespread through low level health facilities ranging from small hospitals to health centers, health post and outreach activities[7] (Jha et al. 2002). A major cause of the disparities in access to maternal health care in Brazil comes from using local financing in the face of very unequal income levels across municipalities. Historic records on the allocation of SUS expenditure for prenatal and antenatal care demonstrate that poorer regions (the North and Northeast) where the majority of poorer municipalities are concentrated receive less expenditure per birth than their wealthier counterparts (World Bank 2002).

Interpretation of our findings should take into consideration the limitations of this study. Since we used cross sectional data to analyze the association between density of

[7] Together making up what is defined to a "close-to-client" health system, defined as consisting of relatively simple hospitals, health centers, and in some circumstances, smaller health posts and their outreach services, along with the infrastructure and personnel directly responsible for the delivery of interventions through categorical programs. People other than doctors can carry out most of the work: that is, nurses and paramedical staff of various degrees of training, including midwives.

health workers and health facilities with the health of the population at municipality level, our findings can not be interpreted as causal effects. There are two main assumptions in this analysis the first is negligible movement across municipalities (as information on utilization and health resources are from the place of residence) and the second is that each municipality devoted the same proportion of resources to each intervention.

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Part III

Population Health

Chapter 6

Sub-national assessment of inequality trends in neonatal and child mortality in Brazil

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Abstract

Objective Brazil's large socioeconomic inequalities together with the increase in neonatal mortality jeopardize the MDG-4 child mortality target by 2015. We measured inequality trends in neonatal and under five mortality across municipalities characterized by their socio-economic status in a period where major pro poor policies were implemented in Brazil to infer whether policies and interventions in newborn and child health have been successful in reaching the poor as well as the better off.

Methods Using data from the 5,507 municipalities in 1991 and 2000, we developed accurate estimates of neonatal mortality at municipality level and used these data to investigate inequality trends in neonatal and under five mortality across municipalities characterized by socio-economic status.

Results Child health policies and interventions have been more effective in reaching the better off than the worst off. Reduction of under five mortality at national level has been achieved by reducing the level of under five mortality among the better off. Poor municipalities suffer from worse newborn and child health than richer municipalities and the poor/rich gaps have increased.

Conclusion Our analysis highlights the importance of monitoring progress on MDGs at sub-national level and measuring inequality gaps to accurately target health and intersectoral policies. Further efforts are required to improve the measurement and monitoring of trends in neonatal and under five mortality at sub-national level, particularly in developing countries and countries with large socioeconomic inequalities.

Introduction

Reducing child mortality by two thirds between 1990 and 2015 is the target of the fourth Millennium Development Goal (MDG). Recent analyses indicate that there has been major progress towards this goal. Current estimates show that the global under five mortality rate (U5MR) dropped from 93 per 1000 live births in 1990 to 72 per 1,000 in 2006 [1].

The targets to measure the progress towards the achievement of the Millennium Development Goals (MDGs) assess the progress of countries at the national level. However, national averages could be misleading, particularly in countries with great inequalities, as progress could be attained by improving the health of the well off while neglecting the health off the worst off. A recent report to monitor progress towards the attainment of the MDGs in 68 priority countries, which account for 97% of all maternal and child deaths, found that the poorest 20% of the population are less likely to be covered by effective interventions capable of preventing most maternal and child deaths than their wealthier counterparts [2]. It is therefore crucial to produce within country estimates to properly monitor progress of the MDGs and share countries' experience on policies and interventions that have been successful in reducing health inequalities and improving the health of the poor.

In the Latin America and Caribbean Region, the large inequalities in living conditions within countries together with the increase in the percentage of U5MR attributed to neonatal mortality jeopardize the MDG-4 target [3]. In Latin America, neonatal mortality represents more than half of overall infant mortality and 42% of under five deaths, and most of the neonatal deaths happen during the early neonatal period [4].

Brazil is the largest economy in Latin America [5] and it is considered to be one of the five most important emerging economies of the world along with Mexico, China, India and South Africa [6]. However, despite Brazil's economic achievements, it is still at the top of the list of countries with the highest income inequalities [7]. The poorest 20 percent earn 2 percent of the income while the richest 20 percent earn 63 percent (figures correspond to 2005, estimated from Pesquisa Nacional por Amostra de Domicilios, 2005) [5].

Brazil's national territory is divided administratively into 5 regions, 27 states and 5,507 municipalities (in 2000). There are wide variations in population, wealth, climate and size across geographical areas. For example, 25% of the municipalities have population below 5,000 inhabitants, while a few have populations above 1,000,000 inhabitants (the largest being the municipality of Sao Paulo with a population of 10.4 million).

In recent decades Brazil has achieved very important health gains [8] and is on track to achieve most of the MDG targets at the national level [9]. National level estimates show major progress in the reduction of U5MR. Between 1990 and 2005 child mortality dropped from 53.7 to 28.7, a declined of 46.6% and infant mortality dropped from

33.7 to 21.1, a declined of 37.4%, a drop of more than one third during the period, suggesting that Brazil is on track to reach the MDG-4 target by 2015 [9].

The health sector reform of the 1990's and the public health and inter-sectoral interventions implemented by the Brazilian government have contributed to the reduction of U5MR.

During the last two decades Brazil has undergone a series of health reforms aimed at: 1) providing universal access to health services free of charge to the entire population (Sistema Unico de Saude (SUS)- Unified Health System), and 2) decentralizing the decision making to the municipality governments (one level below the state). This resulted in the expansion of services, the most significant being the Family Health Program (described in Additional file 1: Appendix 1) (PSF), focused on providing and improving primary health care, particularly maternal and child care, among the poor [10-12]. Other public health and inter-sectoral programs have also been introduced to reduce infant and child deaths, such as access to clean water and sanitation, education of the mothers and immunization coverage. In addition, the federal government launched other programs to fight against hunger and poverty [13], such as the Zero Hunger program (Fome Zero) (described in Additional file 1: Appendix 2) [14] and the cash transfer program (Bolsa Familia) (described in Additional file 1: Appendix 3) [15]. In 2006, 99% of 1 year olds were covered by immunization of measles vaccine (MCV), diphtheria and tetanus toxoid and pertussis vaccine (DPT3), hepatitis B vaccine (HepB) and haemophilus influenza type b (Hib3) and 92% of neonates were protected at birth against neonatal tetanus (PAB) [16].

However, despite the efforts made to improve access to health care services for the poor and the policies implemented to reduce child mortality, in practice there remain major health inequalities. The poorest region (Northeast) had the highest under five mortality rate of 39 per 1000 live births in 2005, whereas richer regions (South and Southeast) had the lowest child mortality rates of around 18.5 per 1000 live births [9]. Moreover, in 2004, 6% of the children less than five years old in the poorest region died from diarrhea, compared to 2% of the children in richer regions [17]. An evaluation of three maternal and child health programs found less access to health care among the poor [18]. A recent study also found that poorer municipalities had a lower proportion of deliveries attended in health facilities (76%) and a lower proportion of pregnant women covered by antenatal care (54%) than richer municipalities (for which the corresponding figures are 91% and 71% respectively) [19]. This is particularly important as most of the deaths of newborns are directly related to inadequate care during and after pregnancy and child birth [4,20].

Although the challenges involved in reducing child mortality are widely recognized, there is not enough evidence currently available to monitor whether newborn and child health interventions have been successful in reaching the poor at municipality level (the

post-reforms level of decision making). Most of the existing evidence in neonatal and child mortality shows differences across regions or states [9,21-24] but very few analyses have been undertaken to monitor inequality trends across municipalities throughout the country [25,26]. Furthermore, evidence suggests that particularly in the poorest regions (North and Northeast), national civil registration data (the only source of information to produce municipal level estimates) are not an accurate source of information on infant deaths [27-30].

In this paper, we develop accurate estimates of neonatal mortality at the municipality level. We then use these estimates to measure inequality trends in neonatal and under five mortality across municipalities characterized by their socio-economic status, in a period where major health reforms and several pro poor policies were implemented in Brazil focused on decreasing child and neonatal mortality. We then infer whether these policies and interventions in newborn and child health have been successful in reaching the poor as well as the better off in Brazil.

Data and methods

To analyze inequality trends in under five and neonatal mortality at the municipality level we constructed a dataset that compiles information on mortality rates and socio-economic indicators for the 5,507 Brazilian municipalities for 1991 and 2000.

The most recent year of analysis is 2000, as it is the year with the most complete and accurate data to monitor differentials in child mortality at municipality level. Brazil has two systems to monitor vital events: the Mortality Information System (SIM) and the Information System on Live Births (SINASC). Several evaluations suggested however that neither system is complete enough to monitor differentials in infant and child mortality [27-30]. It is estimated that the Mortality Information System (SIM) [31] underreports 25% of deaths in the Northern Region and 29% in the Northeastern Region [28]. Similarly, the coverage of the Information System on Live Births (SINASC) [32] is only 73% in these two regions compared to the national coverage of 93% [33]. These inaccuracies are likely to be higher among children under one year of age and in municipalities with less than 50,000 inhabitants [29]. For these reasons we used Census data in this analysis.

Data on the under five mortality rate (described in Additional file 1: Appendix 4) per 1000 live births, estimated from the 1991 and 2000 population Census of Brazil, were obtained from the Institute of Applied Economic Research (IPEA), which compiles and produces publicly available data of socio-economic indicators of the municipalities [34].

The neonatal mortality rates per 1000 live births are a predictive estimate of the under five mortality data. First, we produced sub-national rates of neonatal mortality and

child mortality by applying direct life table methods to birth histories from the various Demographic and Health Surveys (DHS). DHS is a (generally nationally representative) survey designed to collect detailed information on social and demographic characteristics and maternal and child health over a sample of women aged 15 to 49 years old in developing countries. The DHSs of Brazil used in this study were conducted in 1986, 1991 and 1996 and are sub-nationally representative: 1) 1986 is representative at regional level; 2) 1991 was conducted in the North-eastern region and is representative at the state level; and 3) 1996 is representative at the regional level and in four states in the North-eastern region, Rio Grande do Norte, Bahia, Ceará and Pernambuco [35-37]. Second, we used the rates produced from DHS to investigate the relationship between neonatal and under five mortality per 1000 live births at sub-national level using a log-log regression model. In addition, we included binary variables in the models to control for the different years of DHS. Finally, we extrapolated these relationships to predict neonatal mortality rates for the municipalities of the Southern and Northern Regions using the estimates of under five mortality rates (produced from the population Census) at municipality level for 1991 and 2000.

Data on the proportion of population below the poverty line (described in Additional file 1: Appendix 5), were obtained from IPEA [14]. These data were then used to group municipalities by poverty quintiles, where the fifth quintile represents the poorest 20% of municipalities and the first quintile the richest 20%. We also categorize municipalities as poor (the poorest 40%, 2,202 municipalities) or non-poor (the remaining 60%, 3,305 municipalities). The first two quintiles (40% of the municipalities) were considered as poor as they comprise the municipalities with more than 50% of their population below the poverty line.

To monitor whether improvements reached the worst off as well as the better off populations, there are two measures of the extent of mortality inequality. The first one, the relative measure, defined as the ratio of child mortality in the poorest quintile to the richest quintile; and the second one, absolute measure, defined as the difference in mortality between the poorest and richest quintile [38]. We also constructed an index to classify municipalities in four categories depending on the under five mortality reduction between 1991 and 2000 and the level of under five mortality in 2000 to identify the municipalities that require urgent policy interventions.

Results

The results are presented in two subsections (and were produced using STATA 9 and ArcGIS 9.3 [39,40]). First, we show how we produced the data of neonatal mortality at municipality level for 1991 and 2000. Then, using these data and the existing data on

under five mortality, we present the results of inequality trends in neonatal and child mortality across poor and non-poor municipalities in Brazil.

a. Prediction of neonatal mortality

The log-log relationships between neonatal and under five mortality across sub-national units in Brazil are presented in Table 1. We found two different relationships; one for the three southern regions and a second one for the North and Northeast Regions. For the northern regions, a one percent increase in U5MR is associated with a 0.79 percent increase in NNMR, while for the southern regions, a one percent increase in U5MR is associated with 0.94 percent increase in NNMR. For the Southern Regions the model explains 94% of the total variance while for the Northern Regions the model explains 61%. It is likely that there are other socioeconomic characteristics (such as education of the mother) that were not taken into account in the model for the Northern Regions that are likely to explain the remaining variance. None of the dummy variables included in the models to control for differences in the survey years were significant.

We used these relationships to predict neonatal mortality from existing estimates of under five mortality at municipality level for 1991 and 2000. We compared the averages of our predicted estimates of neonatal mortality by region with the numbers produced for the same year by two official sources of information; the Brazilian monitoring report on the MDGs, 2004 [25] and the 2008 Report on Basic Health Indicators (Indicadores

Table 1. Log-log regressions of neonatal mortality on under five mortality among sub-national areas DHS 1986, 1991, 1996

Variable name	Northern Regions	Southern Regions[b]
Ln of U5MR	0.786**	0.940**
	-4.091	-5.113
Years[a]		
Dummy year 1991	-0.076	---
	(-0.472)	---
Dummy year 1996	-0.064	-0.128
	(-0.368)	(-1.335)
_cons	-0.134	-0.373
	(-0.148)	(-0.496)
R2	0.615	0.942
sample	17	9

[a] the reference year is 1986, [b] for the Southern regions there is no DHS data in 1991 as it was conducted among the states of the Northeast Region.

Statistical significance with a * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 2 Comparisons of estimates of neonatal mortality with the estimates of two official sources of information 1) the Brazilian monitoring report on the MDGs 2004 and 2) the 2008 Report on Basic Health Indicators

Region	Indicadores Basicos para saude no Brasil Report (2000)*	MDGs Report NNM (2001)**	Predicted NNM (2000)	
			Mean	[95% CI]
NE	24.5	26.3	25.5	[25.2, 25.7]
N	18.7	18.4	18.3	[17.8, 18.9]
CW	14.2	14.6	14.2	[13.9, 14.6]
SE	12.3	12.5	13.4	[13.1, 13.7]
S	10.9	10.6	10	[9.7, 10.1]

* Estimates are produced using census data for some states [27] and for the remaining states estimates are produced using data for the Mortality Information System (SIM) and from the Live births Information System (SINASC).

** Estimates are produced combining census data and survey data of the Pesquisa Nacional por Amostra de Domicílio - PNAD.

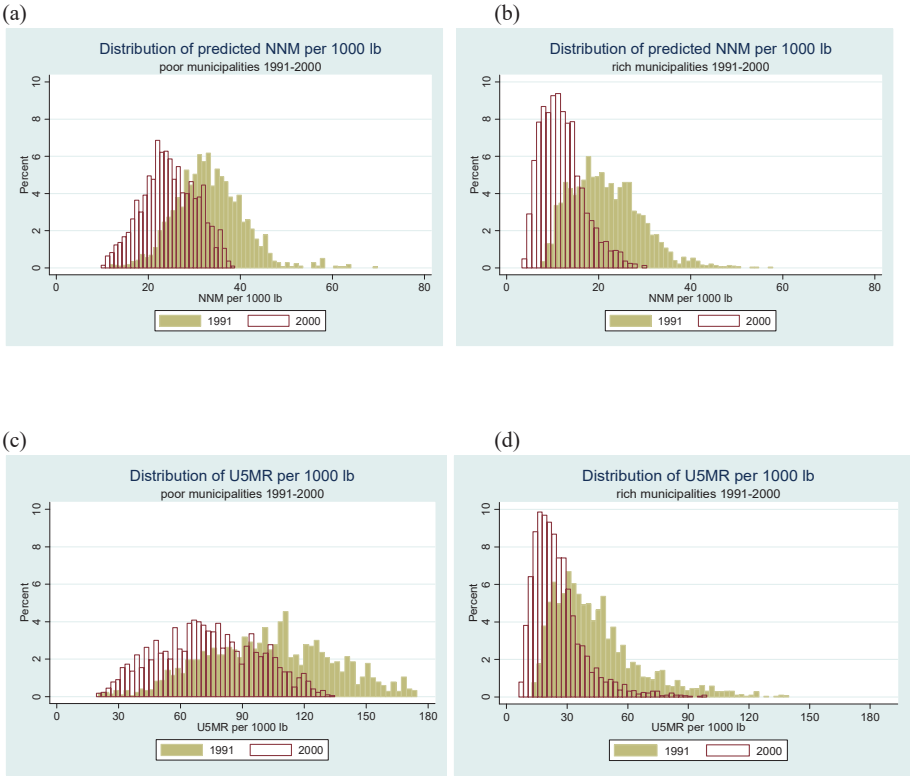
Basicos para Suade no Brasil, 2008) (see Table 2) [17]. We found that our predicted estimates are very similar to the numbers presented in these two reports, which are corrected from the underreporting of deaths in the Northern Regions and used different methods and sources of information to produce their estimates (methods described in the notes of Table 2). This consistency implies that our predicted estimates of neonatal mortality are reasonable and can be used in the analysis presented in the following section. The advantage of our estimates of neonatal mortality is that they can be disaggregated at the municipal level which is the level where the decisions on the administration and provision of services are made.

b. Inequalities in neonatal and under five mortality at sub-national level

The distributions of the predicted neonatal mortality and under five mortality across poor and non-poor municipalities are shown in Figure 1 a, b, c and 1d. In general, we found that between 1991 and 2000 there has been a decline in neonatal and under five mortality across poor and non-poor municipalities. Despite these declines, in 2000, poorer municipalities still have much higher rates of neonatal and under five mortality than richer municipalities.

We looked in more detail at these differences by disaggregating the data into the five poverty quintiles. The average of the predicted neonatal mortality and under-5 mortality across municipalities grouped by poverty quintiles are shown in Figure 2 and in Table 3. Between 1991 and 2000, the averages of neonatal and under five mortality have decreased steadily across all socioeconomic groups. However, we found great inequalities across economic groups: the poorest municipalities had higher neonatal and under

Figure 1 Distribution of under-five mortality and predicted neonatal mortality per 1000 lb by poor and non-poor municipalities in 1991 and 2000



five mortality than any other economic quintile and this problem has not changed over time. For example, the neonatal mortality among the poorest municipalities in 2000 (26.4 per 1000 lb) is similar to the average national rate of this indicator in 1991 and to the national rates of low income countries like Eritrea (24 per 1000 lb) and Kenya (28 per 1000 lb), while the average rate among the richest municipalities (8.7 per 1000 lb) is similar to the national rates of upper-middle-income countries like Mexico and Romania [20].

From the relative ratio between the poorest 20 percent and the richest 20 percent of municipalities, we found that the inequity gaps have also increased in the period analyzed. The poorest municipalities had double the neonatal mortality of the richest municipalities in 1991 and this gap has increased to 3 times higher in 2000. These gaps are even larger in under five mortality: in 1991 the poorest municipalities had U5MRs 3.7 times greater than the richest municipalities and this gap increased to almost five times more in 2000. This implies that the policies and interventions introduced in the late 1980 s and 1990 s are failing to improve the relative position of the poor munici-

Figure 2 Mean of under-five mortality and predicted neonatal mortality per 1000 lb by poverty quintiles, Brazilian municipalities in 1991 and 2000.

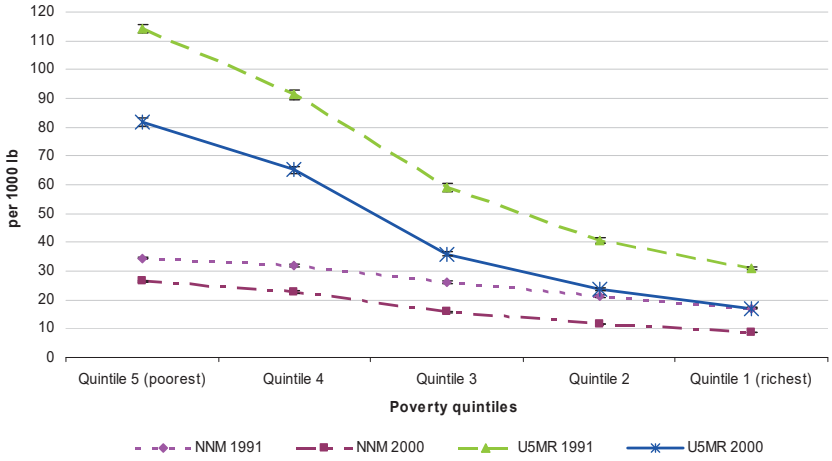


Table 3 Inequality trends in under five mortality and predicted neonatal mortality per 1000 lb by poverty quintiles in 1991 and 2000

	NNM per 1000 lb*				U5MR PER 1000 lb*				Decrease rate 1991-2000	
	1991		2000		1991		2000			
Poverty quintiles	Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI	NNM	U5MR
Quintile 5 (poorest)	34.54	[34.16, 34.92]	26.4	[26.07, 26.73]	114.2	[112.64, 115.85]	81.87	[80.52, 83.21]	24%	28%
Quintile 4	31.89	[31.43, 32.35]	22.71	[22.39, 23.04]	91.38	[89.64, 93.13]	65.21	[63.89, 66.53]	29%	29%
Quintile 3	26.27	[25.82, 26.73]	15.79	[15.51, 16.07]	59.04	[57.59, 60.48]	35.98	[35.09, 36.87]	40%	39%
Quintile 2	21.35	[20.98, 21.72]	11.62	[11.43, 11.81]	40.65	[39.78, 41.52]	23.52	[23.08, 23.96]	46%	42%
Quintile 1 (richest)	17.07	[16.77, 17.37]	8.69	[8.53, 8.84]	30.88	[30.27, 31.49]	17.06	[16.74, 17.38]	49%	45%
National	26.22	[25.98, 26.47]	17.04	[16.83, 17.25]	67.23	[66.21, 68.25]	44.72	[43.94, 45.51]	35%	33%
Inequalities										
Q5/Q1 Ratio	2		3		3.7		4.8			
Q5-Q1 Differential	17.5		17.7		83.4		64.8			

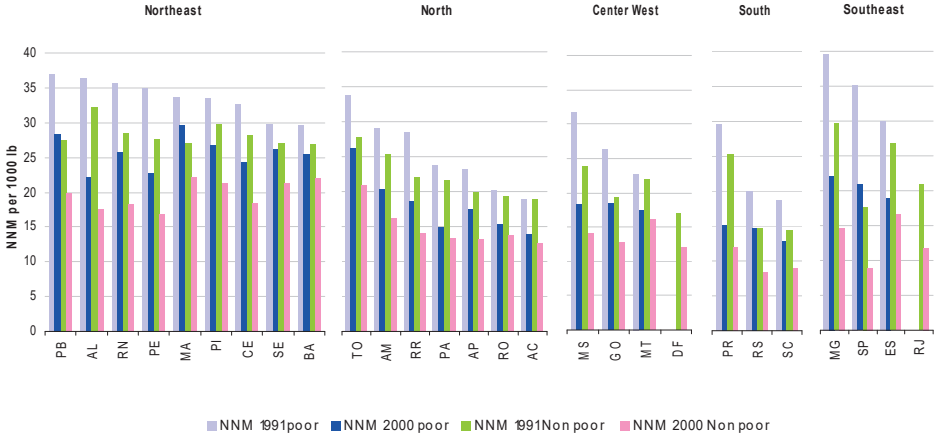
* National estimates differ from official sources due to differences in the sources of information.

palities. The absolute differences show that the neonatal mortality between the poorest and richest municipalities differed by 17.5 deaths in 1991 and 17.7 in 2000, while the difference in under five mortality between these two groups fell from 83 deaths in 1991 to 65 in 2000.

In terms of the decline experienced between 1991 and 2000 at national level, there was a decline of 33% in under five mortality suggesting that Brazil is on track to meet the MDGs' child health target by 2015. However, this decline is not homogenous across poverty quintiles. We found an increasing gradient in the percentage decline by poverty quintiles, such that richer municipalities experienced a faster decline in under five and neonatal mortality than poorer municipalities. For example, the poorest municipalities experienced a reduction of 24% in neonatal mortality and of 28% in under five mortality, while the richest municipalities had a decline of 49% in neonatal mortality and of 45% in under five mortality.

Figure 3 shows that inequalities within regions and states are also very wide we found that inequalities in neonatal mortality between the poor and the rich have increased in a large majority of the states during the period analyzed. However, the highest inequalities were found in states belonging to richer regions -Southern Regions-. For example, we found that the states of Sao Paulo and Rio Grande do Sol had the highest inequalities in neonatal mortality in the country, with a poor non-poor gap of 2.4 and 1.7 in 2000 respectively. These are also the states with the highest inequalities across different socio-economic indicators, which may explain our findings [41,42]. Sao Paulo for example, combines the poorest and the richest populations, thus it is not surprising that we also found the highest inequalities in neonatal mortality.

Figure 3 Predicted neonatal mortality per 1000 lb between poor and rich municipalities within the States and Regions of Brazil in 1991 and 2000.



We related the under-five mortality reduction between 1991 and 2000 with the level of under-five mortality in 2000 across poor and non-poor municipalities (depicted in Figure 4). We added as cut-points the national values of both variables. The cut-point of 33% represents the national decline in under-five mortality between 1991 and 2000 and the cut-point of 33 per 1000 lb represents the level of under-five mortality at national level. From this plot we can observed four groups of municipalities: 1) group one, municipalities with high under five mortality -defined as rates above the national cut point of 33 per 1000 lb- and with low decline -defined as reduction below 33% national decline-; 2) second group, municipalities with low under five mortality -defined as rates below the 33 cut point- and low decline; 3) third group, municipalities with high under five mortality and high decline -defined as reductions above 33% national decline -; and 4) fourth group, municipalities with low under five mortality and high decline.

A large majority (81%) of municipalities in group one -low decline and high under five mortality- are poor municipalities, while almost all (96%) municipalities in group four -high reduction and low under five mortality- are rich municipalities.

For policy purposes, we constructed an index (described in Additional file 1: Appendix 6) using the groups of municipalities of Figure 4 and mapped its distribution across municipalities to identify the critical geographical areas (see Figure 5). Not surprisingly, we found that the majority of municipalities in group one -low decline and high under five mortality- belong to the poorer regions (North and Northeast) where the majority of poor municipalities are concentrated. Specifically, a large majority (60%) of municipalities in this group are concentrated in four states of the Northeast Region: 24.4% in Bahia (identified as BA in Figure 3), 13% in Maranhão (MA), 10.4% in Piauí (PI),

Figure 4 Relationship between under five mortality reduction between 1991 and 2000 and the level of under-five mortality per 1000 lb in 2000 by poor and non-poor municipalities, Brazil.

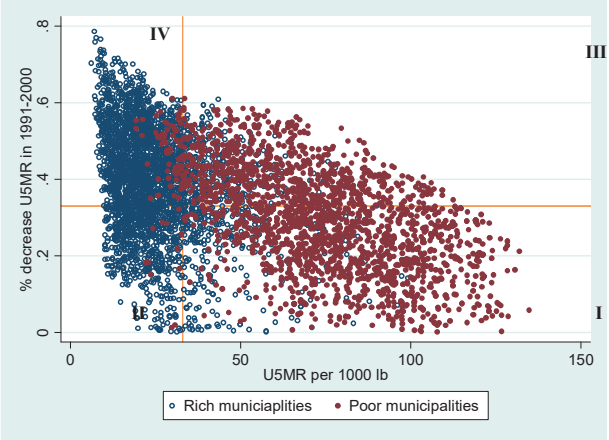
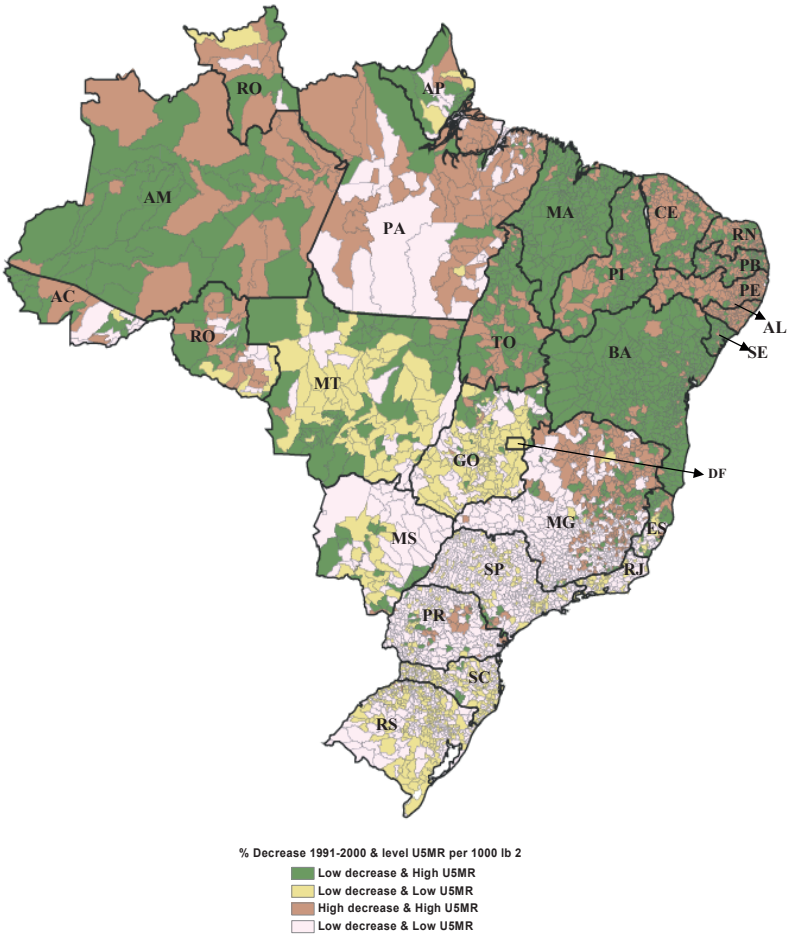


Figure 5 Distribution of municipalities by categories of municipalities grouped by under-five mortality reduction between 1991 and 2000 and the level of under-five mortality in 2000.



and 8.8% in Paraíba (PB), which are also the states were we found the highest levels of neonatal mortality among the poor in Figure 3.

However, we also found other states from wealthier regions with a significant number of municipalities in group one. For example, 47% of the municipalities in Mato Grosso (MS) and 33% of the municipalities in Espirito Santo (ES) were classified in group one despite the fact that these states belong to richer regions like the Center West and Southeast Regions.

Despite the socioeconomic conditions, there are some poor municipalities in the poorer regions that have been successful in reducing under five mortality to levels below 33 per 1000 lb (group three): these municipalities are mainly concentrated in the states

of Pernambuco (PE), Rio Grande do Norte (RN), Alagoas (AL), and Ceará (CE) from the Northeast Region and Pará (PA) from the North Region.

Conclusions

This study highlights the importance of conducting sub national level analysis to monitor progress on MDGs. Sub-national level analysis is also important in countries that have undergone decentralization reforms, specifically at the level where the decisions on the administration and provision of services are made in order to determine whether policies and interventions have been successful in improving the health of the population.

Several policy implications may arise from this study. As shown by the case of Brazil, the policies and interventions focused on improving newborn and child health have been more effective in reaching the better off than the worst off. However, the magnitudes of these inequalities are not shown by the national numbers. We found that the achievement in the reduction of under-five mortality at national level has mainly been reached by reducing the level of under-five mortality among the rich. Poor municipalities suffer from worse newborn and child health than richer municipalities and the poor/rich gaps have further increased, thus jeopardizing the possibility of reaching the MDG-4 target by 2015. These findings are consistent with the report to track progress on the attainment of the MDGs on child and maternal mortality (MDGs 4 and 5) by 2015 [2].

Most of the deaths between one year and five years old are related to infectious disease and could be averted by very cost effective interventions [43]. However despite the implementation of specific interventions to decrease child mortality in poor areas, still 6% of children under five in these areas die from diarrhea [17]. In addition, despite the implementation of actions to increase access to clean water and sanitation among the poor, still 83% of the households in rural areas do not have access to improved drinking water as compare to 9% of the households in urban areas [44]. It is therefore crucial to pursue intersectoral interventions to improve the socioeconomic conditions of poor municipalities.

In the other hand, most of the deaths of newborns could be prevented with access to adequate care during and after pregnancy and child birth [4,20]. However, a recent study found that poorer municipalities had lower proportion of deliveries attended in health facilities and proportions of pregnant women covered by antenatal care than richer municipalities, the differences being attributed to lack of human resources, qualified personnel, and local health facilities [19]. Thus, further efforts are required from municipal, state and federal authorities to make health systems more equitable

and to identify the interventions that have the ability to reach the poor and reduce socioeconomic inequalities in maternal, newborn and child health.

These results contribute to a major understanding of inequalities in newborn and child health within Brazil. Brazil's MDG report 2007, has pointed out that policies and programs should be targeted to improve the health of the population in the poorest Regions (the North and Northeast) to address health inequalities [9]. In this study, we provide further evidence and found that not all the municipalities in these regions require additional policy interventions. In fact, despite being economically disadvantaged, some poor municipalities in the North and Northeast are performing very well and their policies and interventions can be used as an example for further actions by municipalities with similar socioeconomic conditions. Furthermore, the majority of the municipalities with low decline and high levels of under-five mortality have also very high levels of neonatal mortality. These municipalities are concentrated in four states in the Northeast Region, but some are found in richer states and richer regions.

The conclusions drawn from this study should take into consideration the limitations of the data. The data used in this study are from 2000, which is the most recent year with valid estimates of child mortality at municipal level (as pointed out in the methods). It is therefore likely that the level of neonatal and child mortality in this study overestimate the current numbers. Although, several national and sub-national interventions have been implemented to reduce inequalities in neonatal and under five deaths across socioeconomic groups since 2000, the most recent information shows that in general, between 2000 and 2005, there have been relatively few improvements in neonatal and child health inequalities between the poorest and richest regions [9,17].

Data quality may have affected the pattern of our estimates of neonatal mortality in the Northern Regions. We have therefore performed a sensitivity analysis producing the estimates of neonatal mortality for the municipalities in the Northern Regions using the relationship of the Southern Regions (from Table 1). We found that the estimated neonatal mortality in the Northern municipalities is higher if the Southern relationship is used than the estimates when the Northern relationship is used. We also found that the patterns found across municipalities do not change and even more the inequalities are more accentuated when the Southern relationship is used. This implies that the results and conclusions found in this study do not change when using different extrapolation models.

We found that the model of the Northern Regions explains 61% of the total variance while for the Southern Regions it explains 94% of the variance. Although the lack of explanatory power of the model in the Northern relationship may have affected the quality of our estimates the sensitivity analysis demonstrates that the patterns found remain the same even when using different models.

Despite the limitations associated with the data, this study has highlighted some critical issues in terms of the persistent inequalities in neonatal and child mortality within Brazil. This is particularly important for most developing countries and countries with great inequalities, thus further efforts are required to improve the measurement and monitoring of trends in neonatal and under five mortality at sub-national level.

Additional file 1

Appendix 1. This program was implemented in 1994 to expand primary health care particularly to the municipalities that did not have primary health care facilities and to refer patients to more complex levels of care [12].

Appendix 2. The aim of this program is to guarantee the access to basic food by making direct transfers to the poorest families to raise their consumption of food, distributing vitamins and iron supplements, among others [14]

Appendix 3. This program provides financial aid to poor and indigent families conditional on attendance at school for children, updated immunization cards for children under six years old and regular visits to health center for breast feeding or pregnant women [15].

Appendix 4. The under five mortality rates were estimated by applying indirect demographic methods to information from reports of women concerning the survival of their children ever born from the 1991 and 2000 population Census of Brazil [45], using the Coale and Demeny West family table to convert probabilities of dying to mortality levels [27].

Appendix 5. Defined as the proportion of population with a monthly family income per capita of less than 75$R, which is equivalent to half a minimum wage per capita in August 2000. The universe of population is the total number of people with a permanent address. This indicator is constructed from the Population Census.

Appendix 6. 1) group one, municipalities with high under five mortality – defined as rates above the national cut point of 33 per 1000 lb – and with low decline – defined as reduction below 33% national decline; 2) second group, municipalities with low under five mortality – defined as rates below the 33 cut point – and low decline; 3) third group, municipalities with high under five mortality and high decline – defined as reductions above 33% national decline; and 4) fourth group, municipalities with low under five mortality and high decline.

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Chapter 7

Reducing inequities in neonatal mortality through adequate supply of health workers: evidence from newborn health in Brazil

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Abstract

Introduction Progress towards the MDG targets on maternal and child mortality is hindered worldwide by large differentials between poor and rich populations. Using the case of Brazil, we investigate the extent to which policies and interventions seeking to increase the accessibility of health services among the poor have been effective in decreasing neonatal mortality.

Methods With a panel data set for the 4,267 Minimum Comparable Areas (MCA) in Brazil in 1991 and 2000, we use a fixed effect regression model to evaluate the effect of the provision of physicians, nurse professionals, nurse associates and community health workers on neonatal mortality for poor and non-poor areas. We additionally forecasted the neonatal mortality rate in 2005.

Results We find that the provision of health workers is particularly important for neonatal mortality in poor areas. Physicians and especially nurse professionals have been essential in decreasing neonatal mortality: an increase of one nurse professional per 1000 population is associated with a 3.8% reduction in neonatal mortality while an increase of one physician per 1000 population is associated with a 2.3% reduction in neonatal mortality. We also find that nurse associates are less important for neonatal mortality (estimated reduction effect of 1.2%) and that community health workers are not important particularly among the poor. Differences in the provision of health workers explain a large proportion of neonatal mortality.

Discussion In this paper, we show new evidence to inform decision making on maternal and newborn health. Reductions in neonatal mortality in Brazil have been hampered by the unequal distribution of health workers between poor and non-poor areas. Thus, special attention to a more equitable health system is required to allocate the resources in order to improve the health of poor and ensure equitable access to health services to the entire population.

Introduction

Despite appreciable progress, few of the 75 countries that account for more than 95% of all the maternal and child deaths globally are on track to attain the Millennium Development Goals (MDGs) on child and maternal mortality (MDGs 4 and 5) [1], [2]. One of the contributing factors to this slower than anticipated progress has been the lack of access to priority maternal and child health interventions among the poor [3].

In many countries, the levels of current staff are less than the minimum required to deliver health services [4] and in many others, health workers tend to be concentrated in better off areas limiting the access of health services to certain groups of the population [5], [6]. The quantity, distribution and quality of health workers which are accessible to the poor are key constrains for further gains towards the attainment of the MDGs by 2015.

Globally neonatal mortality *(deaths between 0–27 days)* represents 43% of overall under-five deaths and the proportion of under-five mortality attributed to neonatal mortality has increased [7]. In addition, recent figures show that progress towards reducing neonatal mortality rates has been slower in regions with high neonatal deaths [8]. Most of the neonatal mortality occur during the early neonatal period and is associated with inadequate care -lack of access to a functioning health facility or to qualified health professional- during and after pregnancy and child birth [9], [10]. It is therefore crucial that countries share experiences on policies and interventions that have been effective in decreasing neonatal mortality.

Brazil is the largest country with the largest economy in Latin America, but it also has large economic inequalities [11]; around 16 million people live in extreme poverty [12]. In Brazil, neonatal mortality accounts for 71% of infant mortality (this percentage has increased by 30% in the past 21 years) [7] and it is among the top 10 countries with the highest number of preterm births [13].

Over the last two decades Brazil has undergone a series of major health reforms with an emphasis on the universal provision of health services, particularly primary health care, combined with large scale decentralization of decision making. The 1988 constitution mandated universal access to health services and established a decentralized health system. The Single Health System (Sistema Unico de Saude –SUS) established in 1990, provides access to public facilities and pays for access to private facilities. While the system is designed to promote universal access there is a great deal of local autonomy in the level of provision, the pay of public sector workers and the reimbursements to the use of private facilities. Despite the progress made to decrease inequalities between the rich and the poor in several health indicators [14]–[16], major health inequalities remain [6], [17]–[27].

Sousa et al. 2010 & 2012 found that the poorest areas in Brazil suffer from worse neonatal and child health than richer areas and the poor- rich gaps have increased over

time. The poorest states also experienced the highest inequalities in the distribution of physicians plus nurse professionals and at the same time have the highest shortage of skilled health workers [6], [25]–[27]. In this paper we assessed whether the differences in the supply of health workers and skill mix composition have measurable effects in the health of the population particularly on neonatal mortality. We focused on neonatal mortality as most of neonatal deaths could be averted with a functioning health system.

Materials and Methods

To explore the relationship between the supply of health workers and neonatal mortality we constructed a panel data set with three different sources of information for two years, 1991 and 2000, on the 4,267 Minimum Comparable Areas (MCA) in Brazil. MCA is the unit of analysis rather than municipalities (the decentralized level of decision making), as it is the smallest geographical unit comparable between 1991 and 2000 population census. Data on neonatal mortality rate per 1000 live births for 1991 and 2000 are from Sousa et al. 2010a. Using sub-national data of neonatal mortality and child mortality rates from the three sub-national representative Demographic and Health Survey (DHS) conducted in Brazil; 1986, 1991 and 1996; the authors first investigated the relationship between neonatal and under five mortality per 1000 live births at sub-national level for the Southern and Northern Regions in Brazil (using a log-log regression model). They then extrapolated these relationships to predict neonatal mortality rates for the municipalities of the Southern and Northern Regions using publicly available data on under-five mortality per 1000 live births at municipality level for the 1991 and 2000 population censuses [27].

Data on health workers were extracted from the microdata of the population Census 1991 and 2000, using sample weights to produce four categories of health workers in the form of densities per 1000 population: physicians; nurse professionals; nurse associates (technicians, auxiliaries of nursing, nursing assistants, practical midwives and similar); and community health workers [28], [29].

We included as covariates in our analysis, the proportion of population living in urban areas, the population density per km2 and the proportion of population living below the poverty line defined as the proportion of population with a monthly family income per capita of less than 75$R, which is equivalent to half a minimum wage per capita in August 2000 (from the Institute of Applied Economic Research (IPEA) [30]. We then defined poor MCAs as those with more than 50% of population below the poverty line, and non-poor otherwise. Table 1 shows the national mean and standard deviation (SD) of the variables used in this analysis.

Table 1 Descriptive statistics

	1991		2000	
	Mean	**SD**	**Mean**	**SD**
Neonatal mortality per 1000 live births	26.19	8.85	16.85	7.68
Physicians per 1000 population	0.303	0.601	0.320	0.587
Nurse professionals per 1000 population	0.054	0.227	0.112	0.293
Nurse associates per 1000 population	1.889	1.773	2.448	1.800
Community health workers per 1000 population	0.415	0.779	1.207	1.180
Population density per km2	0.122	0.422	0.104	0.313
% of population below the poverty line	57.10%	23.10%	45.40%	22.70%
% of urban population	53.70%	23.20%	61.80%	21.80%

Sources: Data from the population Census 1991 & 2000, the Institute of Applied Economic Research (IPEA) and Sousa A, et al. 2010 for neonatal mortality.

Note: For all variables, differences in the mean values between years are statistically significant except for the density of physicians per 1000 population.

Methods

We used a fixed effect regression model with robust standard errors to evaluate the effect of the provision of health workers on neonatal mortality for poor and non-poor areas in Brazil, in 1991 and 2000. To evaluate the contributions of the different categories of health workers on neonatal mortality we included separately the densities of physicians, nurse professionals, nurse associates and community health workers.

The statistical model used is:

$$\ln(NNM_{it}) = \beta_0 + \boldsymbol{\beta}_1 phy_{it} + \boldsymbol{\beta}_2 np_{it} + \boldsymbol{\beta}_3 na_{it} + \boldsymbol{\beta}_4 chw_{it} + \alpha_k \mathbf{Z}^k_{it} + \mu_i + \eta_t + u_{it} \quad (1)$$

where t = 1,2 and $i = 1, \ldots, n$

where i denotes the i-th MCA, μ_i represents state fixed effects and η_t time fixed effects. The $\mathbf{Z}^k_{it}$ vector of covariates is composed of a dummy for poor areas, the population density per km2 and a dummy for the proportion of the population living in urban areas. We additionally included a dummy variable to control for the fact that there are no health workers in some MCA. We did not include health expenditure as an additional explanatory variable in the model because it is highly correlated with the supply of health workers, as health workers account for approximately 70% of recurrent expenditure in most health systems [4]. We tried other variables such as the proportion of adult women with less than five years of education but it was not considered for the final analysis because of multicolinearity as it is highly correlated with the level of poverty. Moreover,

it had less explanatory power than the variables finally included in the models. We also explored an alternative model, the random effect model, as an alternative specification, but we rejected it based on the Hausman test (rejected $p<0.001$) (which is the formal test for testing statistically significant differences between the coefficients in the time varying explanatory variables to discriminate between Fixed Effect and Random Effects models [31], [32]).

We additionally forecasted the neonatal mortality rate for poor and non-poor areas in 2005 using the predictive model of equation 1 and the density of health workers in 2005 extracted from Datasus [33], [34]. We then measured the trend of neonatal mortality rates between 1991 and 2005 for poor and non-poor areas. The analysis was performed using STATA 11 [35].

Results

To estimate the effect between health worker availability (disaggregated by physicians; nurse professionals; nurse associates; and community health workers) and neonatal mortality rates, three models were estimated. Model 1, shows the results for the entire sample; Model 2, shows the results for poor MCAs and Model 3, for non-poor areas. Table 2 shows the coefficients, the signs and the level of significance of the parameters estimated by the fixed effect regression model with robust standard errors.

In the first regression for all MCAs -Model 1-, we found that, after controlling for municipalities' socioeconomic characteristics, the densities of physicians, nurse professionals and nurse associates have an inverse effect on neonatal mortality and these effects are highly significant. An increase of one physician per 1000 population is associated with a 2.5% reduction in neonatal mortality. Likewise, an increase of one nurse associates per 1000 population is associated with a 1.15% reduction in neonatal mortality. The highest impact is found for nurse professionals; where an increase of one nurse professional per 1000 population is associated with a 4.3% reduction in neonatal mortality. We also found an unexpected and statically significant association between the density of community health workers and neonatal mortality. A decrease in one community health worker per 1000 population is associated with a 1.25% reduction in neonatal mortality. Increasing the availability of all categories of health workers have a highly and significant effect in decreasing neonatal mortality of 6.4%.

When we separated the sample by poor and non-poor areas, in models 2 and 3, we also found that health workers have a significant and strong effect on neonatal mortality for poor and non-poor areas. In poor areas -Model 2-, it tends to be skilled health workers in the form of physicians and nurse professionals what matters for neonatal mortality. We found that the effect of physicians on decreasing neonatal mortality was of 2.3%

Table 2 Fixed-effect regression models of neonatal mortality rates for the MCA in all the sample and separated by poor and non-poor areas in Brazil, 1991–2000.

	All sample Model 1		Poor areas Model 2		Non-poor areas Model 3	
Variables	**Coef.**	**SE**	**Coef.**	**SE**	**Coef.**	**SE**
Physicians per 1000 population	-0.0248***	(0.0054)	-0.0231*	(0.0108)	-0.0310***	(0.0057)
Nurse professionals per 1000 population	-0.0429***	(0.0100)	-0.0384**	(0.0141)	-0.0505***	(0.0114)
Nurse associates per 1000 population	-0.0115***	(0.0018)	-0.0117***	(0.0022)	-0.0083***	(0.0024)
Community health workers per 1000 population	0.0125***	(0.0029)	0.0005	(0.0031)	0.0130**	(0.0045)
Dummy for health workers availability	-0.0642***	(0.0125)	-0.0458**	(0.0145)	-0.0783***	(0.0206)
Dummy urban	-0.0056	(0.0059)	-0.0240***	(0.0063)	0.0041	(0.0116)
Dummy poor	0.2744***	(0.0083)				
Population density	0.0039	(0.0070)	0.0094	(0.0070)	-0.0036	(0.0210)
Dummy year	-0.4483***	(0.0057)	-0.3044***	(0.0068)	-0.5901***	(0.0084)
_cons	2.8878***	(0.0386)	2.9973***	(0.0396)	3.1268***	(0.0399)
N	8534		4471		4063	
r2	0.7825		0.5471		0.6765	
r2_a	0.7816		0.5437		0.6738	

Sources: Author's calculation using data from the population Census 1991 & 2000, the Institute of Applied Economic Research (IPEA) and Sousa A, et al. 2010 for neonatal mortality.

Note: The models control for state fixed effects not presented in the table. Estimates were produced using robust standard errors to adjust for the presence of heteroscedasticity. We used the log of neonatal mortality as dependant variable. Statistical significance with a * p<0.05; ** p<0.01; *** p<0.001. Poor refers to minimum comparable areas (MCA) with more than 50% of population below the poverty line, and non-poor otherwise. In all models, differences in the coefficients between categories of health workers are statically significant except for the densities of physicians and nurse professionals. Differences in the coefficients between poor and non-poor areas are also statistically significant. Other covariates such as the proportion of adult women (over age 15) with less than five years of education (average years) were also explored but not considered for the final analysis because of multicolinearity and for having less explanatory power than the variables finally included in the models.

while for nurse associates the effect was of 1.2%. Likewise, the highest effect on neonatal mortality was found for nurse professionals. An increase of one nurse professionals per 1000 population is associated with a 3.8% reduction in neonatal mortality. We also found that the presence of community health workers in poor areas is not associated with neonatal mortality.

For rich areas -Model 3-, we found that all categories of health workers have an inverse and significant effect on decreasing neonatal mortality except for community health workers which have again an unexpected and statistically significant association with neonatal mortality.

For the three models, the time variable has an inverse and significant relationship with neonatal mortality, which implies that mortality rates decrease over time as an effect of the technological change. We found that the change in technology has contributed to a 30% reduction in NMR in poor areas and to a 59% in non-poor areas. The socioeconomic determinants of neonatal mortality in the regressions are urbanization, population density and the level of poverty. We found that population density is not statistically significant in any of the three models. For all MCAs -Model 1-, poverty is significantly associated with neonatal mortality. In the poor areas -Model 2-, urbanization is inversely associated with neonatal mortality, while for non-poor areas -Model 3- it is not statistically significant.

We found that the total absolute reduction in neonatal mortality for poor areas during the period analysed was of 7.6 deaths per 1000 live births (from 27.9 per 1000 live births in 1991 to 20.3 in 2000). In non-poor areas, the total reduction in neonatal mortality in the same time period was of 9.5 deaths per 1000 live births (from 20.9 per 1000 live births in 1991 to 11.4 in 2000). For policy implications, we estimated the contributions of skilled health workers -physicians and nurse professionals- and unskilled health workers -community health workers and nurse associates- to the reduction of neonatal mortality in poor and non-poor areas (see Table 3). In poor areas the increase of health workers availability has contributed to a 27% reduction of neonatal mortality while in richer areas their contribution has been of 17%. In addition, the marginal effect of raising the number of skilled health workers in poor areas to the average level found in rich areas would decrease the proportion of neonatal mortality by about 6%.

Table 3 Effect of skilled and unskilled health workers availability on neonatal mortality in poor and rich areas.

	Poor areas	Non-poor areas
Explained reduction by skilled health workers	-6.15%	-8.15%
Explained reduction by unskilled health workers	-1.17%	0.47%
Total explained reduction	-7.32%	-7.68%
Total reduction in neonatal mortality between 1991- 2000	7.6	9.5
Percentage explained reduction by skilled health workers	22.80%	18.11%
Percentage explained reduction by all health workers	27.10%	17.10%

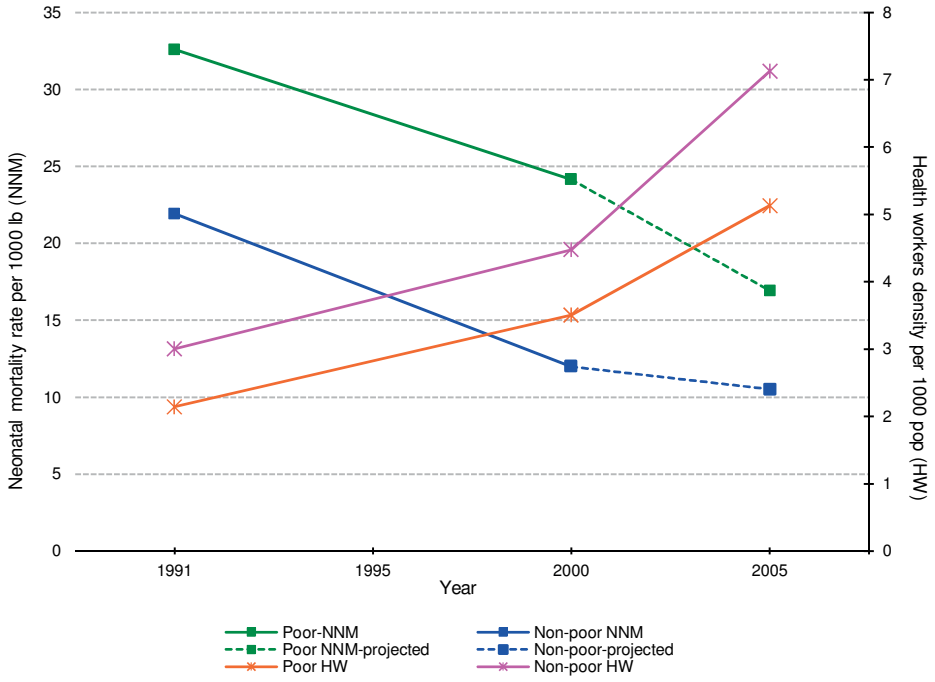
Sources: Author's calculation using the output from Table 2.

Note: Skilled health workers refers to physicians & nurse professional and unskilled health workers to nurse associate & community health workers. Poor refers to minimum comparable areas (MCA) with more than 50% of population below the poverty line, and non-poor otherwise. The explained reduction by skilled health workers for poor and non-poor areas is the sum of the marginal effects estimated in Table 3 for physicians and nurse professionals. Similarly, the explained reduction by unskilled health workers is the sum of the marginal effects for nurse associate and community health worker.

We forecasted the neonatal mortality rate in 2005 using the coefficients from equation 1 and data on the density of health workers per 1000 population from 2005. We found that the projected neonatal mortality rate in 2005 at national level is of 13.1 per 1000 live births, which is similar to the estimated neonatal mortality rate at national level from Barros et al. 2010 of 13.6 in 2007 [20] and to the UN estimates of around 14 per 1000 live births in 2005 [7]. This consistency implies that our projected neonatal mortality rate can be disaggregated for poor and non-poor areas.

Figure 1 shows the trends of the neonatal mortality rate per 1000 live births and health workers density per 1000 population for poor and non-poor areas between 1991 and 2005. In general, we found that between 1991 and 2005 there has been a constant decline in neonatal mortality in both poor and non-poor areas and, at the same time, there has been a sharp growth on the availability of health workers per 1000 population.

Figure 1 Trends of the neonatal mortality rate per 1000 lb 1991–2005.



Sources: Author's calculation using data from the population Census 1991 & 2000, the Institute of Applied Economic Research (IPEA), DATASUS 2005, Sousa A, et al. 2010 for neonatal mortality 1991 & 2000 and projected estimates of neonatal mortality rate 2005 from output table 2. Note: X axis = year. Y axis left = neonatal mortality rate per 1000 lb. Y axis right = health workers density per 1000 pop. Green square = neonatal mortality rate for poor areas. Blue diamond = neonatal mortality rate for non-poor areas. Pink cross = health workers density for non- poor areas. Orange cross = health workers density for poor areas. doi:10.1371/journal.pone.0074772.g001

However we found great inequalities; poorer areas have higher neonatal mortality rate and lower density of health workers than richer areas and this problem has not changed over time. The projected neonatal mortality rate in 2005 in poor areas is of 17 per 1000 live births while for non-poor areas the projected neonatal mortality rate is of 10.5 per 1000 live births.

Discussion

Our analysis suggests that larger gains in neonatal mortality have been hindered by the large differentials in the availability of health workers between the poor and non-poor areas in Brazil. Differences in the provision of skilled health workers explain a large proportion of neonatal mortality in the poorest areas. Thus, policies and interventions seeking to increase the availability of qualified health workers would have a dramatic impact in decreasing neonatal mortality among the poor.

We demonstrated that qualified health workers are essential in decreasing neonatal mortality particularly among the poor. Although nurse professionals have the highest impact on decreasing neonatal mortality, they remain the category of health workers the less deployed across the country. We also found that nurse associates are less important for neonatal mortality and that community health workers do not have an effect particularly among the poor. Since these categories of health workers have mixed skills, training and education, our findings imply that their training on neonatal care should be harmonized across different areas of the country and further strengthened to have an impact on neonatal mortality as demonstrated in other areas of the world. For example, the positive impact of home visits by community health workers on neonatal mortality has been clearly demonstrated by several randomized and non-randomized controlled trials. A meta-analysis of 8 studies involving more than 65,000 babies has showed a significant 63% reduction in neonatal mortality among those newborn babies receiving home visits by a community health worker compared to those who did not receive the intervention [36]–[39].

Other options to increase the accessibility of health services in low resource settings and decrease the rate of neonatal mortality could include: 1) strengthening the education of mid-level health workers; 2) more efficient utilization of health worker time by increasing the productivity of the current health workforce [26]; 3) implementing strategies to retain health workers in underserved areas; and 4) changing the skill mix of health workers by using health workers with less training to carry out a variety of healthcare tasks if they receive appropriate training [40]–[42].

The large socioeconomic and health inequalities that remain in Brazil, together with the percentage increase of neonatal mortality on child mortality, raise major concerns

for further improvements on child mortality [16], [20]. Thus this analysis makes a significant contribution for Brazil and the experience presented in this paper is relevant for other developing countries undergoing similar challenges in decreasing neonatal mortality, as it quantifies the effect of implementing health sector policies to decrease the poor/non-poor gap in neonatal mortality across sub-national areas.

There are some limitations of this analysis that merit consideration. Due to data limitations we have used the same approximation as Farahani et.al. 2010 [43], which considered the number of physicians as a proxy for health system resources in general, and assumed that other inputs usually vary proportionately with the number of health workers, so that our results represent the effect of health inputs as a whole and not just the impact of the number of the different categories of health workers. We have restricted this analysis to the different categories of health workers supply, since panel data on other health resources are lacking for all MCA. Since we account for state fixed effects in our analysis, we have controlled for any confounding variables that are fixed in a state over time. Even though municipality is the level of decision making after the decentralization reform, we did not use municipality as the unit of analysis as it is not comparable over time, the reason being that more than one thousand municipalities were created between 1991 and 2000. We therefore used data of the 4,267 MCAs to eliminate the problem of comparability in the unit of analysis. We used estimates of the neonatal mortality for the MCA produced in Sousa et.al. 2010 [27] as the national civil registration data are not an accurate source of information on neonatal deaths, particularly for the poorest regions in Brazil [44]–[47]. We were also unable to adjust for health workers quality: training, re- training, experience (as measured by length of service) and individual skills for all categories of health workers are key elements to ensure quality services. Although most categories of health workers used in our analysis were clearly defined, the umbrella term "community health worker" embraces a variety of community health aides, which are likely to range from untrained volunteers from the community to well trained professionals. This implies that our results may have been affected by the heterogeneity in the definition of community health workers as well as the impossibility to assess the quality of training and their individual skills. These limitations mean that our results should be interpreted with caution. Further studies, in Brazil as well as in other countries of the world, should be conducted using more recent data to verify the findings of this study.

Despite the limitation of the data, this study has highlighted critical issues in terms of the quantity, distribution and skill mix of health workers which are accessible to the poor. Despite the commitment to universal access to health services in Brazil and expansion of health services among the poor, Sousa et al. 2012 found that in practice poor areas have fewer health workers than rich areas and in addition have the highest inequalities in the distribution of skilled health workers. The majority of the staff in poor areas are

community health workers and poor communities have very few physicians and nurse professionals [6]. In this paper we demonstrated that this lack of provision, relative to richer municipalities, translates into large gaps in neonatal mortality. The evidence in this paper suggests that addressing the imbalances in the distribution of health workers between poor and non-poor areas would be key to improve child health in poor areas. Thus, special attention to a more equitable health system is required to allocate the resources in order to improve the health of poor and ensure equitable access to health services to the entire population to attain universal health coverage.

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Chapter 8

Explaining the inequalities in infant mortality in Mexico: A decomposition analysis

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Abstract

Introduction Over the last two decades Mexico has implemented several policies to reduce maternal and child mortality among the poor and to provide universal access to health services. However large inequalities in maternal and child health remain. In this paper we investigate the determinants of the level and changes of inequality in infant mortality.

Methods Using data of the 2,454 Mexican municipalities for 2000 and 2005, a corrected concentration index decomposition method was used to identify the extent to which socioeconomic inequality in infant mortality can be explained by inequalities in the supply of health workers, utilization of health services, access to health insurance coverage and other covariates.

Results We found that infant mortality has decreased steadily across all levels of deprivation. However, inequity gaps have increased in the period analyzed disfavouring the poor. Most of infant mortality inequalities are due to inequalities in the level of deprivation, to inequalities in unobserved state-level determinants and, to a lower degree, to inequalities in the utilization of attended deliveries in health facilities and health insurance coverage. Having more access to attended deliveries in health facilities decreases infant mortality particularly in poor municipalities. However, having more health workers and health insurance coverage did not decrease infant mortality in poor areas, suggesting that poor people have access to low-quality services.

Discussion The findings from this study suggest that the pro-poor policies introduced in Mexico between 2000 and 2005 have been ineffective in increasing utilization of maternal health services among poor people and decreasing inequalities in infant mortality despite being effective in increasing access to health workers and health insurance coverage among the poor. Thus, further policies should be oriented to ameliorate the quality of the maternal health services that are accessible to poor people to decrease infant mortality inequality.

Introduction

In Latin America, neonatal mortality (*deaths between 0–27 days*) represents more than half of the overall infant mortality and 51% of under-five deaths. Most of the neonatal deaths occur during the early neonatal period (UNICEF 2013) and are associated with inadequate care during and after pregnancy and child birth (WHO 2005, 2006). A shortage of qualified staff, equipment and infrastructure, and their unequal distribution, are often perceived to be among the major obstacles hindering adequate access to priority maternal and child health care.

Among the OECD member states, Mexico has the highest infant mortality of 14 per 1000 live births in 2012 among which neonatal mortality accounts for 52% (UNICEF, 2013). Progress towards reducing neonatal mortality rates has slowed down in recent years: While between 2000 and 2005 the rate of neonatal mortality decreased by 27%, it only decreased by 10% between 2005 and 2012 (UNICEF, 2013).

The main governmental programs implemented between to 2000 and 2005 to alleviate maternal and child mortality among the poor included: 1) the conditional cash transfer program 'Oportunidades' implemented since 1997 which was designed to improve health, education and nutrition of poor families with children (SEDESOL, 2014); and 2) the 'Equal Start in Life programme' or 'Arranque parejo de vida' implemented in 2001 to reduce maternal and perinatal deaths targeted to deprived areas (Orozco-Nunez, 2009).

Since 2003 Mexico has also undertaken a series of major health reforms aimed at providing universal access to health services to the entire population with the 'Seguro Popular-SP' (Popular Health Insurance) programme. Its main targets were poor families previously excluded from social insurance and with no access to any form of private or public coverage (Frenk, 2006). The reform has substantially increased the allocation of financial resources for health to states to cover the new beneficiaries. These health system resources have led to an increased supply of health workers as an important proportion of the resources were specifically allocated to expand the health workforce. However, despite the availability of new financial resources many states did not manage to provide the necessary incentives to attract professional health workers to deprived and rural areas and instead often relied on undergraduate interns who compulsorily have to work in a rural health unit for 6 to 12 months before receiving their degree (Nigenda, 2013).

The expansion of SP coverage has been effective in reducing the catastrophic and out of pocket health expenditure incurred by formerly uninsured poor households (Knaul, 2006; Gakidou, 2006; Galarraga, 2009) and has also increased utilization of health services for the population covered by the SP (Gakidou, 2006; Sosa-Rubi, 2009; Salinas 2009). However, no effect has been found in increasing coverage of maternal and child health care (Gakidou, 2006) or improving the health of the population (King 2009)

particularly on infant mortality. In spite of all governmental efforts to decrease child mortality among the poor, the poorest states still have the highest rates of child and maternal mortality compared with the richest states (Pinzon, 2014; Lozano, 2012; SSA, 2008; Gonzales Perez et al. 2008, Stevens et al. 2008).

Although Mexico is considered to be among the most important emerging economies of the world (Arslanalp, 2014), it struggles with poverty and has large income inequalities. In 2012, 52.3% of the population in Mexico still lived below the national poverty line[8] compared to 53.6% in 2000 (WB, 2014). Sixty one % of the population that live in rural areas are poor compared to 40% in urban areas. Most of the poor population is concentrated in the Southern Region of the country and the most vulnerable and disadvantaged groups are poor and indigenous children (CONEVAL,2009).

This paper has three aims: (i) to measure any change in socioeconomic inequality in infant mortality between 2000 and 2005, (ii) to investigate the determinants of the infant mortality in Mexico at municipality level, and (iii) to identify which factors have contributed to the changes in socio-economic inequalities in infant mortality using a concentration index decomposition method proposed by Wagstaff et al (2003).

Data

We constructed a data set at municipality level that compiles information from five different sources for the 2,454 Mexican municipalities for the years 2000 and 2005. At the time of publication, complete and accurate data to monitor differentials in infant mortality at municipality level were available only for the year 2005.

Infant mortality is regressed on a number of covariates for all municipalities in 2000 and 2005. We included the percentage of attended birth deliveries in health facilities as a direct determinant of infant mortality (Bryce, 2003) as in Mexico, a large majority of infant deaths are due to newborn deaths. We also included health workers availability and the percentage of population with health insurance coverage as indirect determinants of infant mortality as they relate to health service utilization. Additional indirect health determinants are included: the municipality's level of deprivation and state fixed effects to control for unobserved state-level determinants of infant mortality. In a further analysis, we included the various components of the level of deprivation to identify their relative

[8] Since June 2010 the definition of poverty in Mexico changed to consider a multidimensional approach (Diario Oficial 2010). The new definition defines poor population as those with income below the poverty line and with at least one social deprivation indicator such as educational gap, access to health services, access to social security, quality and space of the dwelling, access to basic household services and access to food (CONEVAL 2014). 45.5% of the population are poor based on this multidimensional approach in 2012 (CONEVAL 2013).

contribution to infant mortality: the proportion of illiterate population; the proportion of population living in households without electricity; without piped water inside the residence; without toilet or drain; the proportion of population living in households with earth floors; and, the proportion of overcrowded households.

Data on the density of health workers (nurses and doctors) per 1000 population and births attended in hospital or clinic per 100,000 births were extracted from the registries of the Ministry of Health (Dirección General de Información en Salud, 2000-2005; Subsistema de Administración de Egresos Hospitalarios (SAEH)/ Ministry of Health 2000-2005). Population fractions with health insurance coverage were obtained from the Population Census (Censo de Población y Vivienda 2000 and Conteo de Población 2005/ INEGI). Infant mortality rates per 1000 live births and the level of deprivation of the municipalities were obtained from the National Population Council (CONAPO 2000-2005, CONAPO 2000-2005). The level of deprivation is constructed as a composite measure of different dimensions of socioeconomic development to characterize municipalities and states by level of deprivation. Municipalities are grouped into five categories of deprivation from very high (poorest) to very low (richest) using the Dalenius-Hodges stratification method –more details on the methods can be found in Annex A, CONAPO 2013. The deprivation index has been developed by the Mexican government – National Commission on Population (CONAPO) – to identify geographical priority areas. It has been used by several social programs like "Oportunidades" to target the needed population (CONAPO, 2013).

Methods

We measure socioeconomic inequality in infant mortality with a concentration index, which has the advantage of measuring inequality across the full distribution of deprivation. Applied to bounded variables, like the infant mortality rate, the conventional concentration index suffers from some shortcomings, most notably that the bounds of the index depend on the mean of the outcome which is especially problematic in comparisons across countries and time (Wagstaff 2005, Erreygers 2009). We therefore apply the corrected concentration index as suggested by Erreygers (Erreygers 2009), which avoids this problem but shares characteristics with the standard concentration index: (i) negative values imply that infant mortality is more concentrated among the poor, (ii) if all municipalities would have the same infant mortality the index would equal zero and (iii) transferring mortality from poor to rich municipalities would reduce the index. The interpretation of the corrected concentration index is one of absolute inequality, rather than relative inequality. For variables bounded between zero and 1, the corrected concentration index (C_y) is calculated as follows:

$$C_y = 8\ cov(y_i, R_i) \tag{1}$$

where y_i reflects the infant mortality rate in municipality i and R_i the municipality's fractional rank in the distribution of the deprivation index (ranked from high to low deprivation).

To explain socioeconomic inequalities in infant mortality, we apply the decomposition method as suggested by Wagstaff et al (2003). If we assume y_i can be assumed to be a linear function of K covariates x_k:

$$y_i = \alpha + \Sigma_k \beta_j x_{ji} + \varepsilon_i \tag{2}$$

then the corrected concentration index of y_i can be written as a weighted average of the concentration indices of the explanatory variables[9] C_{x_j} (Erreygers 2009),

$$C_y = 4\ \Sigma_k \beta_j\ \bar{x}_j\ C_{x_j} + GC_\varepsilon \tag{3}$$

where $\bar{x}_j$ refers to the means of the covariates and GC_ε the generalized contribution of the error term.

Estimates were produced using robust standard errors to adjust for the possible presence of heteroscedasticity. Weighted least squares (weighted with the size of the municipality) were performed using STATA 11 (StataCorp, 2005).

Results

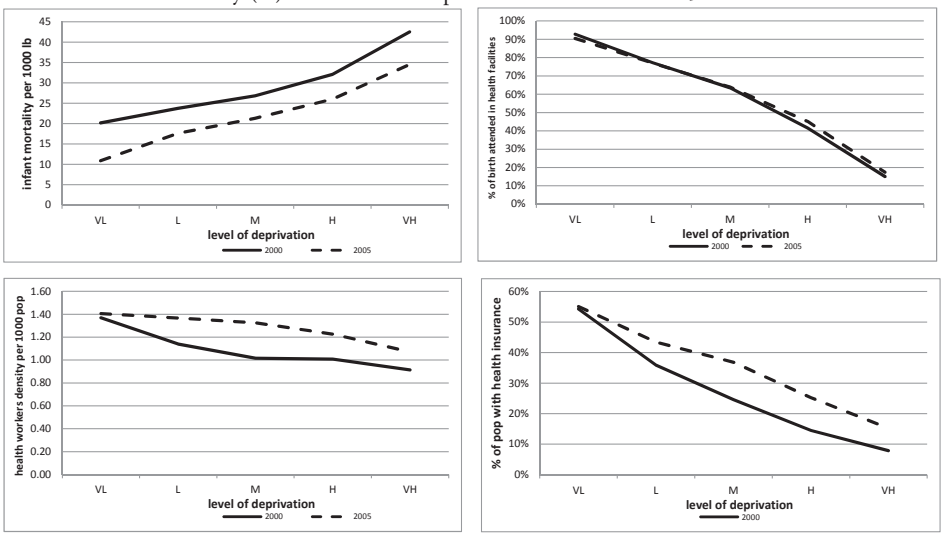
Table 1 and Figure 1 show trends in means and socioeconomic inequalities of infant mortality and its determinants. We find that infant mortality has fallen by about 5-10 deaths per 1000 (in absolute terms) across all levels of deprivation. However, given that the absolute improvement was roughly equal by deprivation level, the absolute gap between rich and poor (as measured by the VL/VH difference and the corrected CI) has not narrowed and the relative inequality (as measured by the VH/VL ratio and the relative CI) has considerably increased. As a result, the poorest municipalities show twice the infant mortality of the richest municipalities in 2000, while triple the rich rate in 2005.

[9] State fixed effects are included in the vector of explanatory variables to control for unobserved state-level determinants of infant mortality.

Table 1 Infant mortality rate per 1000 live births, percentage of births attended in health facilities, health worker density per 1000 population and percentage of population with health insurance coverage by level of deprivation Mexico, 2000-2005

	Infant mortality			Births attended in facilities			Health worker density			Population with health insurance		
Level of deprivation	2000	2005	proportional change	2000	2005	proportional change	2000	2005	proportional change	2000	2005	proportional change
Very low (VL)	20.20	10.85	-46%	93%	90%	-2%	1.37	1.41	3%	54%	55%	1%
Low (L)	23.73	17.60	-26%	77%	77%	0%	1.14	1.37	20%	36%	43%	21%
Median (M)	26.84	21.32	-21%	64%	64%	1%	1.02	1.33	31%	25%	37%	50%
High (H)	32.12	26.00	-19%	42%	45%	9%	1.01	1.23	22%	14%	25%	74%
Very high (VH)	42.55	34.53	-19%	15%	17%	16%	0.91	1.07	17%	8%	15%	93%
National	24.24	15.90	-34%	76%	77%	1%	1.22	1.36	11%	40%	46%	14%
Inequalities												
VH/VL Ratio	2.11	3.18	51%	6.16	5.19	-16%	1.50	1.31	-12%	6.86	3.62	-47%
VH-VL Differential	22.35	23.68	6%	0.78	0.73	-6%	0.45	0.33	-26%	0.46	0.40	-14%
Concentration Index	-0.12	-0.24	97%	0.16	0.14	-13%	0.11	0.06	-48%	0.24	0.15	-37%
Standard error	(0.002)	(0.004)		(0.005)	(0.004)		(0.015)	(0.015)		(0.005)		
Corrected Concentration Index	-0.12	-0.15	30%	0.15	0.13	-13%	0.11	0.06	-48%	0.24	0.15	-38%
Standard error	(0.004)	(0.005)		(0.005)	(0.007)		(0.054)	(0.048)		(0.008)		

Figure 1 Trends in infant mortality (A), births attended in facilities (B), health insurance coverage (C) and health worker density (D) across level of deprivation in 2000 and 2005.



When turning attention to mortality determinants, we see very little change in the unequal distribution of the percentage of births attended in health facilities over the period (Figure 1B), in spite of the governmental programs favouring the poorest regions. In 2005 still almost 90% of women in the richest municipalities deliver their babies with assistance in health facilities compared to only 17% in the poorest municipalities. Greater inequality reductions can be observed for indirect determinants like health worker density (Figure 1D) and health insurance coverage (Figure 1C): greater improvements at higher levels of deprivation have led to lower absolute and relative inequality as indicated by the various measures.

Both the availability of health workers and the level of health insurance coverage have not changed within the lowest level of deprivation.

The observed reductions in inequality in determinants stand in sharp contrast with the relatively unchanged absolute inequality in infant mortality. In what follows, we aim to unravel the reasons for this peculiar finding.

Regression model and decomposition

Table 2 shows regression results for infant mortality in 2000 and 2005 for all municipalities. The coefficient for the fraction of attended deliveries in health facilities is negative and highly significant: a 1 percentage point (pp) increase is associated with a 0.037 pp reduction in infant mortality in 2000 and the association is even stronger (0.043

Table 2 Regression models for infant mortality, 2000-2005

	2000		2005		2000		2005	
	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.
Births attended in hospital or clinic	-0.0372***	0.0038	-0.0434***	0.0065	-0.0139***	0.0028	-0.0317***	0.0054
Health workers density per 1000 pop	-0.0008	0.0005	-0.0003	0.0014	-0.0006	0.0003	0.0018	0.0009
Population with health insurance	-0.0609***	0.0066	-0.0412**	0.0147	-0.0390***	0.0042	-0.0295***	0.0086
Deprivation index *(reference VL)								
Deprivation index (L)	0.0236***	0.0017	0.0746***	0.0039				
Deprivation index (M)	0.0446***	0.0023	0.1124***	0.0049				
Deprivation index (H)	0.0891***	0.0033	0.1646***	0.0070				
Deprivation index (VH)	0.1851***	0.0053	0.2501***	0.0112				
Illiterate pop					0.2489***	0.0117	0.2415***	0.0271
HH without toilet					0.0577***	0.0044	0.1611***	0.0212
HH without piped water					0.0298***	0.0045	0.0516***	0.0094
HH without electricity					0.1201***	0.0087	0.2057***	0.0434
HH with earth floor					0.0722***	0.0053	-0.0015	0.0143
Overcrowded HH					0.0559***	0.0057	0.3178***	0.0173
N	2093		2154		2093		2154	

Note: Health workers density reflect the sum of physicians and nurses density. The models control for state fixed effects not presented in the models. Statistical significance with a * p<0.05; ** p<0.01; *** p<0.001.Robust standard errors are presented in parenthesis. Differences in the coefficients between years areas are statistically significant based on the Chow Test for cross-model equality of the coefficients between 2000 and 2005.

pp) in 2005. We do not find any significant association between infant mortality and health workers density, while the proportion covered by health insurance does show a significant negative association with infant mortality. However, this association fell from an additional 0.06 pp reduction in infant mortality rate per percentage point increase in coverage in 2000 to only 0.04 pp reduction in 2005. By far the strongest predictor of infant mortality is the level of deprivation, with poor municipalities showing much higher infant mortality rates than rich municipalities in both years and the association strengthened over time.

To ascertain which components of deprivation explain most of the infant mortality variation across municipalities, we also estimated the same equation but including the components of the level of deprivation (see the right panel in in Table 5) and found that illiteracy rates, water and sanitation conditions and overcrowding are all strongly related to excess infant mortality.

We then decompose socioeconomic inequality in infant mortality across municipalities for the two years analyzed (see Table 3 and Figure 2). The corrected concentration index went from -0.12 in 2000 to -0.15 in 2005, indicating that the inequality in infant mortality favoring the rich has slightly, but significantly, increased over this period. In both years, the great majority of the inequality is associated with deprivation. The relative contribution of deprivation also increased over the five year period (from 72% to 96%), which is primarily a result of the fact that deprivation has become more strongly

Figure 2 Decomposition of socioeconomic inequality in infant mortality in 2000 and 2005

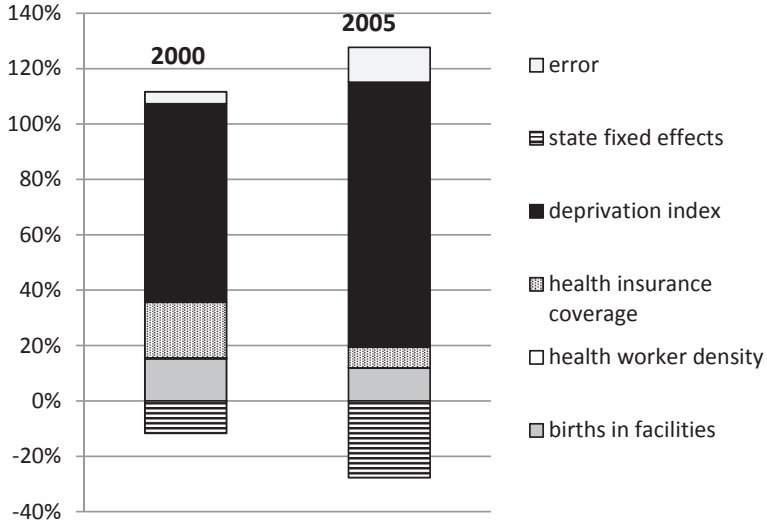


Table 3 Infant mortality inequality decomposition, 2000-2005

	2000				2005			
Variable	Mean	Coef	CI	Contribution	Mean	Coef	CI	Contribution
Births attended in hospital or clinic	0.765	-0.037	0.154	-0.018	0.772	-0.043	0.133	-0.018
Health workers density per 1000 pop	1.222	-0.001	0.115	0.000	1.356	0.000	0.060	0.000
Population with health insurance	0.404	-0.061	0.237	-0.023	0.462	-0.041	0.147	-0.011
Deprivation index * (reference VL)				-0.083				-0.144
Deprivation index (L)	0.158	0.024	-0.244	-0.004	0.149	0.075	-0.305	-0.014
Deprivation index (M)	0.120	0.045	-0.522	-0.011	0.113	0.112	-0.567	-0.029
Deprivation index (H)	0.137	0.089	-0.778	-0.038	0.120	0.165	-0.800	-0.063
Deprivation index (VH)	0.042	0.185	-0.958	-0.030	0.040	0.250	-0.960	-0.039
FE				0.013				0.042
Residual				-0.005				-0.019
CCI* infant mortality				-0.116				-0.151

Note: Health workers density is the sum of physicians and nurses density. The models control for state fixed effects not presented in the models. CCI refers to corrected concentration index.

associated with infant mortality over time. The contribution of health worker density to inequality in infant mortality is negligent, driven by the very small associations identified in the regression model. Because the coefficients of attended deliveries and health insurance coverage are much greater than that of health worker density, their contribution to inequality in infant mortality is more important, respectively 15% and 20%. The changes over time are interesting: while the contribution of attended deliveries has remained relatively similar (12%), the contribution of insurance coverage has decreased quite substantially (from 20% to 7%). This appears to be mainly a consequence of the fact that health insurance has become somewhat less concentrated among the less deprived and associated less with infant mortality.

State level unobservables contribute negatively to inequality in infant mortality, and this contribution has increased from 2000 to 2005 (from -12% to -28%).

In 2005, most of the inequalities in infant mortality are explained by inequalities in the level of deprivation and by inequalities in the state fixed effects (which account for unobservable correlates of both infant mortality and level of deprivation). The increased contribution of state fixed effects suggests that between-state inequality has increased.

Heterogeneity of effects across deprivation

To better understand why inequalities in infant mortality have been so persistent despite pro-poor targeting of demand and supply side policies, we examine heterogeneity in the relationship between covariates and infant mortality. Table 4 shows regression results for both years for the full sample and for poor (very high and high deprivation) and non-poor samples. The association between attended deliveries in facilities and infant mortality appears stronger among the poor in the two years analysed. However, in poor municipalities, the density of health workers is not significantly associated with infant mortality in both years whereas in rich areas the density of health workers has a much larger association in decreasing infant mortality in 2000 but this association is not significant in 2005. This may suggest the existence of differences in the quality of health workers deployed in poor and non-poor areas, as many deprived and rural facilities with the highest infant mortality are covered by undergraduate interns. These health workers normally lack the necessary competences and experience to provide quality health services. One third of rural health units in the country have an intern as their only available practitioner (Nigenda 2013).

While health insurance coverage is quite strongly related to infant mortality in both groups in 2000, the relationship disappears among the poor in 2005. This is consistent with our previous finding (Table 6) which showed that the lack of health insurance has become less concentrated among the poor and therefore less predictive of infant mortality among the poor.

Table 4 Regression models for infant mortality in poor and non-poor areas, 2000-2005

	2000			2005		
Variable	All	Poor	Non poor	All	Poor	Non poor
Births attended in hospital or clinic	-3.7239***	-7.1552***	-1.9371***	-4.3412***	-6.8667***	-3.9196***
	(0.3821)	(0.7048)	(0.353)	(0.6474)	(0.9545)	(0.6969)
Health workers density per 1000 pop	-0.0762	0.2809	-0.1144**	-0.0314	0.0641	-0.149
	(0.0464)	(0.1751)	(0.0392)	(0.1411)	(0.2372)	(0.1391)
Population with health insurance	-6.0944***	-6.1913***	-5.8619***	-4.1229**	-2.9493	-7.0385***
	(0.6634)	(1.6904)	(0.7057)	(1.4663)	(1.5743)	(1.9106)
Deprivation index[a]						
Deprivation index (L)	2.3570***			7.4645***		
	(0.1738)			(0.3922)		
Deprivation index (M)	4.4577***		2.6317***	11.2367***		6.8741***
	(0.2309)		(0.1706)	(0.494)		(0.3755)
Deprivation index (H)	8.9131***		4.9507***	16.4649***		10.1148***
	(0.3302)		(0.23)	(0.7045)		(0.5395)
Deprivation index (VH) (poorest)	18.5069***	8.5425***		25.0139***	8.0862***	
	(0.5287)	(0.4154)		(1.1208)	(0.6531)	
_cons	26.3233***	36.0760***	26.7429***	19.6781***	35.3777***	20.0660***
	(0.6546)	(0.8074)	(0.6625)	(1.5623)	(0.5098)	(1.7361)
N	2093	1002	1091	2154	1010	1144
r2	0.9214	0.7073	0.8671	0.7987	0.6527	0.7168

Note: Health workers density is the sum of physicians and nurses density. The models control for state fixed effects not presented in the models. Statistical significance with a * p<0.05; ** p<0.01; *** p<0.001.Robust standard errors are presented in parenthesis.. Poor refers to municipalities with very high and high level of deprivation, non-poor otherwise. Differences in the coefficients between poor and non-poor areas are statistically significant based on the Chow Test for cross-model equality of the coefficients between rich and poor municipalities.

Conclusions

The aim of this study was to identify the determinants of inequalities in infant mortality and the factors which have contributed to the changes in these inequalities over time in Mexico. We found that infant mortality has decreased steadily across all levels of deprivation. However, inequity gaps have increased in the period analyzed disfavouring the poor.

The policies introduced between 2000 and 2005 have been effective in increasing the supply of health workers and increasing the coverage of health insurance among the poor. These resulted in largely decreasing the inequalities in these two indicators over time. However these policies have been ineffective in increasing utilization of attended deliveries in health facilities among the poor and decreasing inequalities in infant mortality. Around 17% of the women in the poorest municipalities deliver their babies with assistance in health facilities compared to almost 90% of women in the richest municipalities in 2005 and this has remained almost constant over time.

With the decomposition analysis we found that most of infant mortality inequalities in 2000 and 2005 are due to inequalities in the level of deprivation, to inequalities in unobserved determinants and, to a lower degree, to inequalities in the utilization of attended deliveries in health facilities and health insurance coverage whereas inequalities in the distribution of health workers do not contribute to infant mortality inequality.

We found that having more access to attended deliveries in health facilities decreases infant mortality particularly in poor municipalities. However, we found that having more health workers did not decrease infant mortality particularly in poor municipalities. This result may suggest the existence of differences in the quality of health workers deployed in poor and non-poor areas. Increasing health workers supply to increase access to health services in poor areas may not necessarily translate in lower infant mortality if the quality of health services is not guaranteed. The risks of unexperienced practitioners providing care to these populations could be avoided if an appropriate policy would be implemented. Indeed the system currently accounts with financial resources to substitute residents with licensed doctors, nurses and specialists (Nigenda 2013). Thus further efforts should be oriented to increase the quality of the health workers deployed in rural areas to ensure equitable access to quality services to the entire population and therefore have an effect in decreasing infant mortality among the poor.

We also found that having more access to health insurance coverage did not decrease infant mortality in 2005 particularly in poor municipalities. This implies that the implementation of the popular insurance in 2003 which target was to increase access to health services among poor populations which were previously uninsured did not have an effect in decreasing infant mortality among the poor. This could be due to low quality services and to the fact that the popular insurance in the period analyzed was

partially implemented with a subset of interventions in areas comprising health facilities and targeting a fraction of the population. However, it is important to highlight that no studies have been able to prove the positive effect of the popular insurance on the health of the population (King 2009). The main proven effects have been on reducing catastrophic health expenditure (Knaul, 2006; Gakidou, 2006, Galarraga 2009) and increased utilization of health services among the population affiliated to the popular insurance (Gakidou 2006, Sosa-Rubi, 2009; Salinas 2009).

Since 52% of infant deaths in Mexico are due to neonatal deaths further policies should be oriented to ameliorate the quality of the maternal health services that are accessible to the poor to decrease infant mortality among the poor and decrease the inequality as most of the neonatal deaths could be averted with access to maternal health services before and after delivery.

The conclusions drawn from this study should take into consideration the limitations of the data. We have restricted our analyses to the supply of physicians and nurses, since panel data on other health resources were lacking for all municipalities. We did not include health expenditure as an additional explanatory variable in the model because it is highly correlated with the supply of health workers, as health workers account for approximately 70% of recurrent expenditure in most health systems (WHO, 2006). Although we can infer differences in quality of health workers deployed between poor and non-poor areas we were unable to adjust for health workers quality as we didn't have information on training, continued training, experience (as measured by length of service) or individual skills of the health workers. We restricted the analyses to 2005 as it is the most recent year with complete and accurate data to monitor differentials in infant mortality at municipality level. We however note that this period entailed the pilot face of the implementation of the Popular Health Insurance.

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Chapter 9

General Discussion

This thesis investigated whether some of the health sector policies (mostly on health workforce) and interventions implemented in Mexico and Brazil have been successful in reducing maternal and child health inequalities and improving the health of poor people. These countries were selected because they have large inequalities in maternal and child health, and since these inequalities were perceived as being inequitable[10], both countries have implemented several policies in past decades to reduce them. They are also the largest countries in Latin America accounting for more than half of the total population of the region.

A framework was conceived to encompass and link the main elements of health systems: financing, production process, health service utilization and the population's health. It also acknowledged and took into account the influences of social determinants on access, utilization and health outcomes.

I. Findings by chapter

Production Process

The first issue that was covered in this thesis involved the production process of health care. Special attention was given to health workers' availability as there is very little evidence on the association between health workers availability and maternal and child health inequalities at subnational level.

In chapter two, a framework was proposed that describes the health labour market thread and the different health workforce policies required to ensure equitable access to quality services for the entire population. These policies include: 1) policies on production of new graduates; 2) policies to address inflows and outflows of health workers; 3) polices to address mal-distribution and inefficiencies; and 4) policies to regulate the private sector. This study described the possible faults of developing partial health workforce policies to address health workforce shortages. For example, policies designed to scale up the production of new graduates will be very limited in increasing the availability of health workers to provide quality health services to the entire population if the labour market capacity to employ (economic and fiscal capacity for workforce deployment and remuneration) and retain health workers is not in place. If training policies are implemented in isolation there is a risk of increasing unemployment and brain drain and wasting resources. This implies that policies on production will only be effective if they are designed in parallel with policies to ensure the absorption of new

[10] Health inequities are defined as the unfair and avoidable differences in health status seen within and between countries [12].

graduates into the labour market and to correct for workforce mal-distribution and inefficiencies. This study argues that policies to address health workforce challenges in many low- and middle-income countries have been ineffective because were designed ignoring the dynamics of the health labour market.

In chapter three, an analysis was presented that measures changes in inequalities in the densities of health workers across subnational areas in Brazil over the period 1991-2005. The Gini, Theil T and Thel L index methods were used on data from the 4,267 Brazilian Minimum Comparable Areas (MCA) in the years 1991, 2000 and 2005 to measure inequality trends in the densities of different categories of health workers (physicians, nurse professionals, nurse associates and community health workers). The Theil index method was decomposed to distinguish between-group from within-group components of inequality, for states, poverty quintiles, and urban-rural stratum. This study found that between 1991 and 2005 there was an increase in the density of health workers per 1000 population. However, a sharper growth is found among unskilled health workers[11] – nurse associates and community health workers – compared to skilled health workers. Despite these increases, great inequalities were found in access to health services. Skilled health workers – physicians and nurse professionals – were the categories of health workers more unequally distributed across the MCAs and although these inequalities have decreased between 1991 to 2000 they have remain unchanged between 2000 and 2005. Most of the overall inequalities in the distribution of skilled health workers across the MCAs were due to inequalities within states which account for 80% of overall inequality; inequalities within poverty quintiles which account for around 60% of the overall inequality (being the poorest quintile the most unequal); and inequalities within rural-urban stratum which account for around 70% of the overall inequality (being the rural stratum the most unequal). The poorest states experienced the highest inequalities in the distribution of skilled health workers and at the same time had the highest shortage of skilled health workers compared to their richer counterparts. The majority of the staff in the poorest areas were unskilled health workers such as nurse associates and community health workers.

Health service utilization/ intermediate outcomes

Two studies were undertaken to examine inequalities in the utilization of maternal and child health services.

[11] In Brazil physicians and nurse professionals are considered as skilled health workers as they have university education, while nurse associates and community health workers have high school and vocational courses and therefore are considered as non-skilled health workers.

In chapter four, an analysis to quantify socio-economic and geographical inequalities in unsafe abortion[12] was undertaken using data of the pregnancy calendar of the National Demographic Survey (ENADID) of Mexico in 2006. A logistic regression was used to identify the determinants of induced and unsafe abortion. This study found that the most significant determinant of having an induced abortion is whether the pregnancy was wanted/mistimed or not and whether the women had three or more children at the time of the abortion. Forty-four percent of abortions were induced and 16.5% of those abortions were unsafe. The probability of having an unsafe abortion is nine times higher for poor indigenous and uneducated women compared with rich, educated not indigenous women. Large geographical inequalities were found as women living in the poorest states have a higher risk of having an unsafe abortion and at the same time have less knowledge and use of modern contraceptive methods.

In chapter five, an analysis was presented to investigate the relationship between health resources and the utilization of maternal health services between poor and non-poor areas in Brazil in 2000. Using data from the 5,507 Brazilian municipalities, a production function approach was used to investigate the relationship between the supply of health workers (physicians, nurse professionals, nurse associates and community health workers), health facilities (ambulatory units, hospitals and hospital beds), quality indicators in the form of private (versus public) provision, salary levels and other covariates, with access to antenatal care and attended deliveries between poor and non-poor areas. A seemingly unrelated Tobit regression model with corner solution application was used for this purpose. This study found great inequalities in maternal and child health services, poorer municipalities had lower proportions of deliveries attended in health facilities and proportions of pregnant women covered by antenatal care than richer municipalities. When looking at the multivariate relationships it was found that utilization of maternal and child health services rises with the provision of facilities and health workers. In poor municipalities utilization also rises with local access to facilities, private rather than public provision of services and highly qualified health workers.

Population health/ impact outcomes

Different studies were undertaken to measure inequalities in neonatal, infant and child mortality across socioeconomic groups and to identify the sources of the disparities.

In the first of these studies, chapter six, an analysis on the measurement of inequalities on neonatal and child mortality across subnational areas in Brazil over the period

[12] Unsafe abortion was defined in this study as a 'procedure for terminating an unintended/unwanted pregnancy either by individuals without the necessary skills or in an environment that does not conform to minimum medical standards, or both' based on WHO definition (WHO, 1992)

1991-2000 was presented. New estimates on neonatal mortality at municipality level were developed using a log-log regression model for the Southern and Northern Regions of Brazil on subnational level data from the Demographic and Health Surveys (1986, 1991 and 1996) and extrapolated to available estimates of under-five mortality at municipality level from the Census 1991 and 2000. These new estimates on neonatal mortality were used to investigate inequality trends in the distribution of neonatal and under-five mortality rates across the 5,507 Brazilian municipalities characterized by socio-economic status. This study found great inequalities in neonatal and child mortality, poor municipalities suffer from worse newborn and child health than richer municipalities and the poor/rich gaps have increased over time.

Chapter seven brought the data and analyses of chapters three and six a step further to investigate the relationship between the provision of health workers and other covariates on neonatal mortality for poor and non-poor areas in Brazil over the period 1991-2000. A fixed effect regression model was used for this purpose using data from the 4,267 Brazilian Minimum Comparable Areas (MCA) of Brazil. This study found that the provision of health workers is particularly important for neonatal mortality in poor areas. Physicians and especially nurse professionals have been essential in decreasing neonatal mortality. Increases in the density of nurse professionals are highly associated with decreases in neonatal mortality, despite being the health personnel less frequently deployed across the country. Nurse associates are less important for neonatal mortality and community health workers do not have an effect on neonatal mortality, particularly among poor people.

In the previous chapters of this thesis the differences between poor and non-poor areas were examined. In chapter eight, the analysis is expanded using the full distribution to identify the determinants of the level and changes of inequality in infant mortality in Mexico over the period 2000 and 2005. Using data of the 2,454 Mexican municipalities, a concentration index decomposition method was used to identify the extent to which socioeconomic inequality in infant mortality can be explained by inequalities in the supply of health workers, utilization of health services, access to health insurance coverage and other covariates. This study found that in the period analyzed inequality in infant mortality has slightly increased, inequality in the percentage of births attended in health facilities has slightly decreased and inequalities in the density of health workers and health insurance coverage have largely decreased. Most of infant mortality inequalities in 2000 and 2005 are due to inequalities in the level of deprivation, to inequalities in unobserved state-level determinants and, to a lower degree, to inequalities in the utilization of attended deliveries in health facilities and health insurance coverage. Inequalities in the distribution of health workers do not contribute to infant mortality inequality, because of the weak association between health workers and infant mortality. This study also found that access to maternal health services reduced infant mortality

in poor municipalities while access to health insurance coverage and health workers did not have an effect. The findings from this study suggest that the pro-poor policies introduced between 2000 and 2005 have been effective in decreasing the inequalities in the coverage of health insurance and the supply of health workers over time. However, these policies have been ineffective in increasing utilization of maternal health services among poor people and decreasing inequalities in infant mortality; 52% of infant deaths are due to neonatal deaths which can be averted with access to maternal health services before and after delivery.

II. Findings across chapters

In chapter three and eight, it was found that people in poor areas in both countries have fewer qualified health workers to provide health services than their richer counterparts. In Brazil it was found that high shortages and large inequalities in the distribution of skilled health workers have remained unchanged over time. In Mexico the inequalities in the distribution of skilled health workers were not that high and had decreased over time. The majority of staff in poor areas in Brazil are unskilled health workers. These results suggest that the health sector policies implemented in both countries to enhance the local accessibility of health services in the poorest areas - notably with the expansion of health services from the universal health coverage -reforms have been effective in Mexico. In contrast, in Brazil these policies have not been sufficient, because the expansion of health services for poor municipalities in reality means access to unskilled health workers such as nurse associates and community health workers who have mixed skills and education[13]. Several factors have been identified as the main obstacles for attracting skilled health workers to underserved areas in Brazil such as: poor infrastructure, fear of violence, few career development prospects, unreliable remuneration (due to precarious hiring practices), few job opportunities for spouses or good schools for their children [1].

In chapters four, five and eight it was found that poor municipalities in both countries have less utilization of maternal and child health services than their richer counterparts. In Brazil (chapter five) 73% of the women in the poorest areas have an attended delivery compared with 92% of the women in the richest areas. Forty-nine percent of pregnant women in the poorest areas have antenatal care visits compared to 82% in the richest areas (in 2000). In Mexico (chapter eight) 17% of women in the poorest areas have an attended delivery compared to 92% in the richest areas (in 2005) and this difference has remained almost unchanged over time. In Mexico (chapter four) the poorest women

[13] These health workers have high school and vocational courses.

also have less access to reproductive health services and higher rates of unsafe abortion. The high gaps in utilization of maternal and child health services in Mexico (chapters four and eight) in contrast with the low inequalities in the availability of health workers and the increase in coverage of health insurance among poor people (chapter eight) imply that women are not demanding health services despite them being available. This suggests low quality of maternal and child health services. The lack of health services, timely care, adequate infrastructure, and economic resources converge with low quality, discrimination and cultural gaps, all of which have been identified as barriers for women to demand health services in Mexico [4]. These results suggest that the pro-poor policies implemented in both countries to increase access to maternal and child health services have not been sufficient and there are still large inequalities in the utilization of maternal and child health services in both countries.

In chapter five, further explorations were carried out into what inequalities in the availability of health resources between poor and non-poor areas (chapter three) meant to utilization of maternal and child health services in Brazil. Findings showed that inequalities in the utilization of maternal and child health services between poor and non/poor areas are highly associated with low access to human resources, qualified personnel and local facilities among poor people, in contrast with the Mexico situation (chapter eight). Long queues at hospital emergency departments, beds spilling into corridors, outdated and malfunctioning equipment and a scarcity of doctors and medicine have been reported as the main obstacles in the demand of health services in Brazil [2]. These problems have been linked to the lack of financial resources from federal, state and municipal governments [3].

In chapters six and eight, it was found that poor municipalities in Mexico have higher rates of infant mortality and child and neonatal mortality in Brazil than their richer counterparts and these inequalities have grown over time in both countries. The majority of infant deaths in Mexico and child deaths in Brazil are due to newborn deaths, which account for more than half of the infant and child mortality rate. These results suggest that decreasing neonatal, infant and child mortality inequalities are still great challenges in both countries and further policies to improve child health should be oriented to tackle the newborn component.

Most neonatal deaths could be averted with access to a functioning health facility or to qualified health workers during and after pregnancy and childbirth [5, 6]. In chapters seven and eight, further studies examined what inequalities in access to health care services meant to neonatal mortality and infant mortality in Mexico and Brazil. In Brazil (chapter seven) the differences in neonatal mortality between poor and non-poor areas were highly associated with lower access to qualified personnel, particularly nurse professionals in poor areas. This implies that increasing the quantity and distribution of qualified personnel could decrease newborn deaths among poor people and could

largely decrease the inequalities in maternal and child health in Brazil. In contrast no association was found in Mexico between health workers availability and infant mortality. Decreases in infant mortality among poor people in Mexico were associated with increases in the utilization of maternal and child health services. The lack of association between health workers availability and infant mortality is likely to be a result of the low-quality services that are accessible to poor people which hampers the demand of health services from members of the population with the highest need, as already highlighted. Previous studies have found that one third of the primary care units in the public system in Mexico are covered exclusively by newly-graduated physicians completing mandatory public service; these health workers normally lack the necessary competences and experience to provide quality health services [7]. In 2012 Mexico attained Universal Health Coverage, although it has been highlighted that there are still deficiencies in the availability of health resources to provide quality care [8]. These studies suggest that the pro-poor policies and interventions focused on increasing the accessibility of maternal and child health services in both countries have not been sufficient to improve the health of poor people.

III. Policy implications

In summary, this thesis found that over the past decades, there have been great improvements in maternal and child health in Mexico and Brazil. However, despite these improvements, there are persistent inequalities in all the six key health service utilization and population health indicators used in this research: unsafe abortion, coverage of antenatal care, attended deliveries in health facilities, neonatal mortality, infant mortality and child mortality. The results of this thesis demonstrate that the pro-poor health and inter-sectoral policies focused on improving maternal and child health have not been sufficient to reduce inequalities in maternal and child health.

The findings show that poorer areas have fewer qualified health workers than richer areas. Perfect equality in the distribution of health workers is not feasible and in many cases not even desirable. For example teaching hospitals must be strategically located and a concentration of certain types of health workers around hospitals can be completely acceptable (WHR 2006). However in this thesis, findings show that the lack of provision of health services to poor areas relative to rich areas in Brazil and Mexico translates into large gaps in access to health services and poor health outcomes. In Brazil the main problems are the high shortage of qualified health workers, mal-distribution of health workers and a poor skill mix composition. In Mexico the main problem is the low quality of health workers that are accessible to poor people. These results imply that poorer areas have difficulty in attracting and retaining qualified health workers. This

lack of health workforce capacity to provide health services to the entire population is a major challenge for ensuring equitable access to quality health services and universal health coverage.

In Brazil, further health workforce policies to ensure that all children and women have access to quality maternal, newborn and child health should be directed to increase the supply of qualified health workers in poor areas, decrease the unequal distribution of qualified health workers and improve the skill mix composition of health workers. In Mexico policies should be directed to improve the quality of the health workers that are accessible to poor people and improve the skill mix composition of health workers. These policies will need to be designed considering the dynamics of the health labour market and should specifically focus in Mexico on:

1) Strengthening the education of the current health workforce to increase quality and performance;
2) Implementing strategies to retain health workers in underserved areas, such as improving the working conditions and incentives to attract and retain qualified health workers in the poorest areas and;
3) Changing the skill mix of health workers by using health workers with less training to carry out a variety of healthcare tasks usually carried out by doctors, if they have received appropriate training. In both countries there is a tendency for specialization [2, 9].

In Brazil these same policies should be implemented but in parallel with policies oriented in:

1) Training more health workers with the appropriate skills and education;
2) Locally training and recruiting health workers;
3) More efficient utilization of health worker time by increasing the productivity of the current health workforce. A report from the World Bank suggests that in some health facilities in Brazil physicians completed on average only 75% of their contracted work hours [10] and;
4) Ensuring that the newly-trained health workers are absorbed in the labour market with appropriate financial space and vacancies which implies alignment in financing between federal, state and municipal governments (as decentralization of decision-making is at municipality level).

All the studies of this thesis found that social determinants are highly associated to inequalities in newborn, maternal and child health. Although most of the recent literature points out that social determinants are mostly responsible for health inequities [11, 12] this thesis demonstrates that there is still much that could be done to decrease inequities if appropriate health sector interventions are implemented. The results imply that a mix between health sector strategies and strategies to improve socioeconomic determinants, will have important impacts on service utilization and health outcomes among the poor.

The most recent study, which looked at the association between the density of doctors and child mortality, found that the effects of resource increases on child mortality are small in the medium term (five years) but large in the long term (15-20 years) making it hard to achieve the MDGs in the short term [13]. It is also likely that the effects of improvements of socioeconomic characteristics would be attained in the medium and long term.

Despite the political commitment to universal coverage in Mexico and Brazil, in practice, poor municipalities still have access to fewer qualified health workers and health resources than rich municipalities. Their rates of health service utilization are still much lower and therefore health outcomes are worse. The evidence in this thesis suggests that addressing the quality of health services and the imbalances in the distribution of qualified health workers between poor and non-poor areas as well as addressing inequalities in other social determinants of health would be key factors to improve maternal and child health in poor areas in both countries. Special attention to a more equitable health system is required to allocate resources in order to improve the health of poor people and attain equitable access to quality services for the entire population. This will help make further progress towards the attainment of the MDGs at subnational level and attain universal health coverage.

IV. Further research

In this thesis, findings showed strong associations between the density of health workers and the health of the population at municipality level, even after controlling for socioeconomic characteristics. However, these results cannot be interpreted as causal effects as they do not correct for possible sources of endogeneity in the supply of health workers. Previous studies to establish the associations between health and health workers densities across countries [14-18] were also unable to infer causal effect.

There are two possible sources of endogeneity in the association of health workers densities and health outcomes. The first source is due to omitted variable bias which arises when unobserved heterogeneity variables have been omitted from the models that are likely to be correlated with the supply of health workers. Fixed effects estimations can be used with panel data to estimate the effects of time-varying independent variables in the presence of time-constant omitted variables [19] as performed in chapter seven. However these types of models do not solve the problems of time-varying omitted variables that are correlated with the explanatory variables. The models used in this thesis do control for socioeconomic factors that are likely to account for some of the time-varying confounders such as education or level of poverty, however there are possibly other confounders not included in the models such as good government.

The second source of endogeneity is due to simultaneity which arises when one or more of the explanatory variables is jointly determined with the dependent variable. In this case, the supply of health workers is associated with the level of mortality or utilization, however health authorities in a country are likely to define the number of health workers in a certain period based on past patterns of mortality and service utilization. To solve the problem of endogeneity, an instrumental variable model could be used if a suitable instrument is found that is uncorrelated with the error term and is correlated with the endogenous explanatory variables [19]. However such natural experiments with exogenous variations in health inputs are rare. The most recent study to look at these associations across countries, used a panel data designed with a dynamic model [13]. Thus further research should be aimed at measuring causals effects to obtain consistent estimates of the effect of health workers on health outcomes at subnational level.

We used data on the number of health workers per capita (headcounts), as there is no available data on Full Time Equivalent (FTE). By using headcounts it is likely that our results overestimate the real availability of health workers; the implicit assumption is that all health workers work the same amount of time. Further research should be undertaken measuring the real availability of health workers using FTE to measure the productivity of the health workforce. However, these measures are in many cases not available or difficult to gather. More attention should therefore be given to ensure that data on health workers at subnational level includes FTE.

The private training of new graduates and the provision of health services is increasing in many countries. Further research should be undertaken making the distinction between public and private health workers. This is particularly important as there are many concerns about the poorer quality of health workers in the private sector and the provision of private health services; in many countries the private sector is not well regulated. For example, evidence from Philippines demonstrated that the expansion of private nursing schools driven by the global shortage of nurses has exacerbated the imbalance in skill-mix composition of health workers in the country, deplete the health-care system and impoverished the quality of nursing education [20]. Chapter five includes data on the public and private sector, however the data was limited for just one year for Brazil. Further research should be undertaken using data from the public and private sector. Since data on the private sector are normally difficult to obtain, more attention should be given to ensure that data collection includes information from the private sector.

The focused was on health workers' availability because there is very little evidence on the associations between health and health workers densities at subnational level. Previous studies which established these associations used data across countries [13-18]. Although other resources are likely to increase proportionally with the number of health workers (as proposed by Farahani et al. 2009), further research should be undertaken

including other inputs of the production of health care such as capital and equipment. These different inputs are included in chapter five but the data was limited to one year and only for Brazil. These data are, in many cases, not available or difficult to gather. More attention should therefore be given to collect data on all the inputs of the production process of health care at subnational level and across time.

Several specific data limitations relevant to each study such as the differences in data comparability across units of analysis, lack of available data to control for health workers' quality and others have been highlighted in previous chapters. Further attention should be given to improve and update the information at subnational level of all the indicators used in this research to monitor progress at sub-national level and measure inequality gaps over time to accurately target health and inter-sectoral policies.

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English summary

Weak health systems with a shortage of qualified staff, and lack of equipment and medicines impede the delivery of quality health care that is required to prevent maternal and newborn deaths and the attainment of the health-related Millennium Development Goals (MDGs). Using the cases of Mexico and Brazil, this thesis investigated whether some of the health sector policies (mostly on health workforce) and interventions implemented in Mexico and Brazil have been successful in reducing maternal and child health inequalities and improving the health of poor people.

Mexico and Brazil are classified as upper middle-income countries and are the largest countries in Latin America accounting for more than half of the total population of the region. However, despite their economic achievements, both countries struggle with poverty and have large inequalities in maternal and child health.

Over the last two decades the Mexican and Brazilian governments have implemented several public health and inter-sectoral interventions to reduce maternal and child mortality among the poor and have also undertaken a series of major health reforms to provide universal access to health services. However, despite their efforts to increase poor peoples' access to maternal and child health services there is surprisingly little evidence of the effect these policies had in reducing inequalities at sub-national level. Indeed, one of the major challenges for both countries remains the reduction of maternal and child health inequalities at subnational level.

A framework was conceived to encompass and link the main elements of health systems: financing, production process, health service utilization and the population's health. It also acknowledged and took into account the influences of social determinants on access, utilization and health outcomes.

The first issue that was covered in this thesis involved the production process of health care. Special attention was given to health workers' availability as there is very little evidence on the association between health workers availability and maternal and child health inequalities at subnational level. In chapter two, a framework was proposed that describes the health labour market thread and the different health workforce policies required to ensure equitable access to quality services for the entire population. In chapter three, an analysis was presented that measures changes in inequalities in the densities of health workers across subnational areas and identify the sources of the inequalities in Brazil over time.

Two studies were undertaken to examine inequalities in utilization of maternal and child health services. The first study in chapter four, explores the relationship between unsafe abortion and various socioeconomic and demographic characteristics using data

of Mexico. The study in chapter five, further explores the findings of chapter three on access to maternal and child health to investigate the relationship between health resources and the utilization of maternal health services between poor and non-poor areas in Brazil.

Three studies were undertaken to measure inequalities in neonatal, infant and child mortality and to explore whether increases in the utilization of health care services have led to improved health outcomes. In chapter six, new data on neonatal mortality at subnational level are produced and used to measure inequality trends in neonatal and child mortality in Brazil. Chapter seven brought the data and analyses of chapters three and six a step further to investigate the relationship between the supply of health workers and other covariates on neonatal mortality for poor and non-poor areas in Brazil over time. In chapter eight, the analysis of inequalities was expanded using the full distribution to identify the determinants of the level and changes of inequality in infant mortality in Mexico over time.

In summary, this thesis found that over the past decades, there have been great improvements in maternal and child health in Mexico and Brazil. However, despite these improvements, there are persistent inequalities in all the six key health service utilization and population health indicators used in this research: unsafe abortion, coverage of antenatal care, attended deliveries in health facilities, neonatal mortality, infant mortality and child mortality. The results of this thesis demonstrate that the pro-poor health and inter-sectoral policies focused on improving maternal and child health have not been sufficient to reduce inequalities in maternal and child health.

Despite the political commitment to universal coverage in Mexico and Brazil, in practice, poor municipalities still have access to fewer qualified health workers and health resources than rich municipalities. Their rates of health service utilization are still much lower and therefore health outcomes are worse. The evidence in this thesis suggests that addressing the quality of health services and the imbalances in the distribution of qualified health workers between poor and non-poor areas as well as addressing inequalities in other social determinants of health would be key factors to improve maternal and child health in poor areas in both countries. Special attention to a more equitable health system is required to allocate resources in order to improve the health of poor people and attain equitable access to quality services for the entire population. This will help make further progress towards the attainment of the MDGs at subnational level and attain universal health coverage.

Samenvatting

Zwakke stelsels voor gezondheidszorg met een tekort aan gekwalificeerd personeel en een gebrek aan apparatuur en geneesmiddelen belemmeren de levering van kwalitatief goede gezondheidszorg die nodig is om sterfte van moeders en pasgeboren kinderen te voorkomen en de gezondheidsgerelateerde millenniumdoelen voor ontwikkeling (MDG's) te halen. Aan de hand van de casus Mexico en Brazilië wordt in dit proefschrift onderzocht of een deel van de in Mexico en Brazilië uitgevoerde interventies en beleidsmaatregelen ten aanzien van de gezondheidszorg (voornamelijk met betrekking tot gezondheidswerkers) hebben geleid tot een verkleining van de ongelijkheden op het gebied van de gezondheid van moeder en kind en een verbetering van de gezondheid van armen.

Mexico en Brazilië behoren tot de categorie hogere-middeninkomenslanden en zijn de grootste landen in Latijns-Amerika, die samen meer dan de helft van de totale bevolking van de regio uitmaken. Ondanks hun economische prestaties worstelen beide landen met armoede en grote ongelijkheden op het gebied van de gezondheid van moeder en kind.

De Mexicaanse en de Braziliaanse overheid hebben de afgelopen twee decennia verschillende interventies in de gezondheidszorg en intersectorale interventies uitgevoerd om de moeder- en kindersterfte onder de armen te verlagen. Daarnaast hebben zij een reeks belangrijke hervormingen in de gezondheidszorg doorgevoerd om universele toegang tot de gezondheidszorg te kunnen bieden. Ondanks hun pogingen om de toegang van armen tot gezondheidszorg voor moeder en kind te verbeteren is er verbazingwekkend weinig bewijs waaruit blijkt dat dit beleid effect heeft op het verkleinen van ongelijkheden op subnationaal niveau. De verkleining van ongelijkheden op het gebied van de gezondheid van moeder en kind op subnationaal niveau vormt voor beide landen zelfs nog steeds een van de grootste uitdagingen.

Er werd een raamwerk opgezet waarin de belangrijkste elementen van stelsels voor gezondheidszorg zijn opgenomen en aan elkaar zijn gekoppeld: financiering, productieproces, benutting van de gezondheidszorg en volksgezondheid. Hierbij werd ook rekening gehouden met de invloeden van sociale determinanten op toegang, benutting en gezondheidsuitkomsten.

De eerste kwestie die in dit proefschrift wordt behandeld betreft het productieproces van de gezondheidszorg. Hierbij wordt met name aandacht besteed aan de beschikbaarheid van gezondheidswerkers aangezien er zeer weinig bewijs is voor het verband tussen de beschikbaarheid van gezondheidswerkers en ongelijkheden op het gebied van de gezondheid van moeder en kind op subnationaal niveau. In hoofdstuk twee

wordt een raamwerk voorgesteld dat een beschrijving bevat van de zorgarbeidsmarkt en de verschillende beleidsmaatregelen inzake gezondheidswerkers die nodig zijn om gelijke toegang tot kwalitatief goede diensten voor de gehele bevolking te waarborgen. In hoofdstuk drie wordt een analyse gepresenteerd waarbij de veranderingen ten aanzien van ongelijkheden in de dichtheid van gezondheidswerkers in verschillende subnationale regio's worden gemeten en de oorzaken van de ongelijkheden in Brazilië over een langere tijd worden aangewezen.

Er werden twee onderzoeken uitgevoerd waarin werd gekeken naar de ongelijkheden bij de benutting van gezondheidszorg voor moeder en kind. In het eerste onderzoek, in hoofdstuk vier, wordt de relatie tussen onveilige abortus en diverse sociaaleconomische en demografische kenmerken verkend op basis van de gegevens voor Mexico. In het onderzoek in hoofdstuk vijf worden de bevindingen uit hoofdstuk drie over toegang tot de gezondheidszorg voor moeder en kind verder verkend om meer te weten te komen over de relatie tussen middelen voor de gezondheidszorg en de benutting van de gezondheidszorg voor moeders in arme regio's ten opzichte van die in niet-arme regio's in Brazilië.

Er werden drie onderzoeken uitgevoerd om ongelijkheden wat betreft de sterfte van pasgeborenen, zuigelingen en kinderen te meten en te verkennen of een stijging van de benutting van de gezondheidszorg tot betere gezondheidsuitkomsten heeft geleid. In hoofdstuk zes worden nieuwe gegevens over sterfte van pasgeborenen op subnationaal niveau gepresenteerd en gebruikt om ongelijkheidstrends in de sterfte van pasgeborenen en kinderen in Brazilië te meten. In hoofdstuk zeven worden de gegevens en analyses uit hoofdstuk drie en zes verder onderzocht met het oog op het effect van het aanbod van gezondheidswerkers en andere covariaten op de sterfte van pasgeborenen in arme en niet-arme regio's in Brazilië over een langere tijd. In hoofdstuk acht wordt de analyse van ongelijkheden verbreed door aan de hand van de volledige verspreiding de determinanten inzake het niveau van ongelijkheid en de veranderingen in ongelijkheid bij de sterfte van zuigelingen in Mexico over een langere tijd te bepalen.

Kort gezegd wordt in dit proefschrift vastgesteld dat er de afgelopen decennia in Mexico en Brazilië aanzienlijke verbeteringen hebben plaatsgevonden wat betreft de gezondheid van moeder en kind. Ondanks deze verbeteringen is er echter sprake van aanhoudende ongelijkheden met betrekking tot alle zes de belangrijke indicatoren voor de benutting van de gezondheidszorg en de volksgezondheid die in dit onderzoek werden gehanteerd: onveilige abortus, dekking van prenatale zorg, begeleide bevallingen in zorginstellingen, sterfte van pasgeborenen, sterfte van zuigelingen en sterfte van kinderen. De resultaten van dit proefschrift wijzen uit dat het gezondheidsbeleid ten behoeve van de armen en het intersectorale beleid, beide gericht op verbetering van de gezondheid van moeder en kind, ontoereikend waren om ongelijkheden wat betreft de gezondheid van moeder en kind te verkleinen.

Ondanks het politieke streven naar universele dekking in Mexico en Brazilië hebben arme gemeenten in de praktijk nog steeds toegang tot een kleiner aantal gekwalificeerde gezondheidswerkers en middelen voor de gezondheidszorg dan rijke gemeenten. Het percentage voor de benutting van de gezondheidszorg is in arme gemeenten nog steeds veel lager en de gezondheidsuitkomsten zijn er derhalve slechter. Het bewijs in dit proefschrift duidt erop dat de aanpak van de kwaliteit van de gezondheidszorg en de disbalans in de verdeling van gekwalificeerde gezondheidswerkers tussen arme en niet-arme regio's alsook de aanpak van ongelijkheden op het gebied van andere sociale gezondheidsdeterminanten belangrijke factoren zijn bij het verbeteren van de gezondheid van moeder en kind in arme regio's in beide landen. Bij de toekenning van middelen dient bijzondere aandacht te worden besteed aan een billijker stelsels voor gezondheidszorg om de gezondheid van armen te verbeteren en gelijke toegang tot kwalitatief goede diensten voor de gehele bevolking te waarborgen. Op deze wijze kan verdere vooruitgang geboekt worden op weg naar het behalen van de MDG's op subnationaal niveau en het bereiken van universele dekking van de gezondheidszorg.

Curriculum Vitae

Angelica Sousa studied economics at the Universidad Iberoamericana, Mexico City. Before finalizing her last year of bachelor's studies she joined the Mexican Health Foundation -FUNSALUD- to work as a research assistant on the analysis of health inequality, equity and poverty in Mexico. She then obtained a Master in Science degree in health economics at the Center for Research and Teaching of Economics -CIDE-, Mexico City. She then worked as a research associate at the National Institute of Public Health -INSP-, Cuernavaca where she designed a model to evaluate the social costs of illegal abortion in Mexico. Angelica then worked as a consultant for the Mexican Institute of Social Security –IMSS- and Analitica Consultores where she contributed to the evaluation of the program to increase access to health services to poor people in Mexico for the World Bank. She then joined the Mexican Federal Ministry of Health, Mexico City where she lead the analytical work to monitor and evaluate health inequalities and inequities in Mexico and contributed to the cost effectiveness analysis of the Popular Insurance. In 2002, Angelica was invited to join the Equity group in the World Health Organization, Geneva where she worked in monitoring health inequalities across and within countries and health workforce inefficiencies. In 2006, Angelica earned a fellowship at the Harvard Initiative for Global Health, Cambridge where she worked on the analysis of maternal and child inequalities in Mexico and Brazil. After her fellowship, in 2008, she became visiting scientist at the Harvard Center for Population and Development Studies, position that she held during three years.

Since 2009, Angelica is working in the Department for Heath Workforce in the World Health Organization. She develops methodologies, and advises countries on health labour market, health workforce inequalities, productivity and performance.

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