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Equity and economic evaluation of population- and system-level interventions in low- and middle-income countries: an application to the Brazilian *Programa Saúde da Família*

Abstract

Distributional economic evaluation estimates the value for money of health interventions in terms of population health and health equity impacts. When applied to interventions delivered at the population- or health system-level (PSIs) instead of clinical interventions, additional practical and methodological challenges arise. Using the example of the *Programa Saúde da Família* (PSF) in Brazil, a community-level primary care system intervention, we seek to illustrate these challenges and provide potential solutions. We use a distributional cost-effectiveness analysis (DCEA) approach to evaluate the impact of the PSF on population health and between-state health inequalities in Brazil. Data on baseline health status, disease prevalence and PSF effectiveness are extracted from the literature and incorporated into a Markov model to estimate the long-term impacts in terms of disability-adjusted life years. The inequality and average health impacts are analysed simultaneously using health-related social welfare functions. Uncertainty is computed using Monte Carlo simulation. The DCEA encountered several challenges in the context of PSIs. Non-randomised, quasi-experimental methods may not be powered to identify treatment effect heterogeneity estimates to inform a decision model. PSIs are more likely to be funded from multiple public sector budgets, complicating the calculation of health opportunity costs. We estimate a cost-per-DALY of funding the PSF of $2,640. Net benefits were positive across the likely range of intervention cost. Social welfare analysis indicates that, compared to gains in average health, changes in health inequalities accounted for a small proportion of the total welfare improvement, even at

high levels of social inequality aversion. Evidence on the population health and health equity impacts of PSIs can be incorporated into economic evaluation methods, although with additional complexity and assumptions. The case study results indicate that the PSF is likely to be cost-effective, but that the inequality impacts are small and highly uncertain.

Introduction

Alongside improving overall population health, health equity has emerged as a prominent topic and policy objective in global health, as seen, for instance, in both the UN Sustainable Development Goal 3.8 (United Nations, 2020) and the broader universal health coverage (UHC) agenda. Both initiatives call for actions to improve health, to provide a more equitable distribution of health and to improve health-related financial risk protection. At the same time, achieving UHC in many low- and middle-income countries (LMICs) requires substantive health system-level investments, which have strong potential for improving equity and population health (Kieny et al., 2017).

Economic evaluation is typically concerned with the incremental costs and benefits of funding an intervention for the average recipient. This evidence is widely used to assess the efficiency of investments and disinvestments in interventions involving new medicines, medical devices, and diagnostics. Economic evaluation can also be applied more broadly to analyse others types of health system investments, including the value of improving implementation (Faria et al., 2017) and of conducting further research (Griffin et al., 2010). Our focus here is on the issues that arise when conducting an economic evaluation of population and system-level interventions (PSIs) whilst simultaneously taking into account the within-population distribution of the impacts. PSIs may include large-scale public health interventions, health financing initiatives, and health-system level interventions (e.g. changes to health service delivery). The complexities involved in the *standard* economic evaluation (i.e. focused on average health effects) of PSIs have been identified in other recent work (Pandya et al., 2018; Sutton et al., 2018). However, the additional challenges of evaluating them in a *distributional* economic evaluation framework, such as Distributional Cost-

Effectiveness Analysis (DCEA) and Extended Cost-Effectiveness Analysis (ECEA) (Asaria et al., 2016; Verguet et al., 2016), have yet to be explored.

In this paper, we outline issues that arise when explicitly incorporating equity into health economic evaluations of PSIs, paying particular attention to an LMIC context. Although equity ranks as an important decision-making criterion for both policymakers and the general public, formal analysis in economic evaluations is rare (Dawkins et al., 2018; Johri and Norheim, 2012; Weatherly et al., 2009). The challenges for extending these methods to evaluate PSIs are illustrated through a case-study DCEA evaluation of the Family Health Program ('*Programa Saúde da Família*', hereafter PSF), a major, population-wide Brazilian primary care system-level policy.

Overview of the PSF

The PSF is a community-based approach to primary healthcare provision that was introduced in the early 1990s and has seen continual expansion since. In 2014, coverage was estimated to be 120 million people (62% of the population) (Macinko and Harris, 2015). A central objective of the PSF was to improve access to the healthcare system for socioeconomically disadvantaged populations who were not seeking appropriate care (Escorel et al., 2007). PSF teams consist of a physician, a nurse and between four and six community health workers (CHWs) covering non-overlapping catchment areas of approximately 1,000 households. Each household is allocated to one of the CHWs, who conducts a monthly visit to provide advice, identify health issues and risk factors and support adherence to treatments and medications. The organization of the PSF team is designed to ensure that the CHW component is fully integrated with both the local communities they serve and the wider

health system. This was intended to overcome problems that have been encountered with CHW programmes in other contexts (Lehmann and Sanders, 2007).

Methods

This section describes the steps required to conduct a distributional economic evaluation. For each step, the issues relating to the evaluation of PSIs are discussed, followed by a description of the data and methods used to develop the PSF case study analysis.

Analytical approach

Health equity can be defined as *unfair* differences in healthcare access, utilisation, quality or health outcomes (World Health Organization, 2020). These differences can exist with respect to a wide range of sociodemographic variables, most notably socioeconomic status, ethnicity or geography. Different analytical approaches are available to capture such differences and should be selected based on the objectives of the policy under consideration. Empirical analyses of healthcare coverage and utilisation data can be used to shed light on changes in healthcare access (Ridde et al., 2013), although it remains rare for these to be accompanied by a cost analysis. Distributional economic evaluation approaches have so far incorporated equity in terms of health inequality impacts or financial risk protection (FRP) (Asaria et al., 2016; Verguet et al., 2016). These approaches provide decision-makers with evidence on potential trade-offs between equity and the total population health effect, such as when an intervention increases average health but also increases unfair health inequalities. Regardless of which approach is used, it is important that the effects are estimated net of the opportunity costs for each outcome (i.e. the access/FRP/health that would have otherwise been generated had the resources been spent on other interventions).

We elected to use DCEA to evaluate the PSF to investigate the trade-off between the population health gains and geographical inequalities in Brazil. Evidence was available on the heterogeneous impact of the PSF on health outcomes, unlike for healthcare utilisation or FRP (Macinko and Mendonça, 2018). Our analysis focuses on state-level inequalities, which are of interest in Brazil and have been the focus of previous research (Albuquerque et al., 2017; Leite et al., 2015; Marinho et al., 2018). This entails the social value judgement that geographical inequalities in lifetime health are unfair and that reducing them by improving the outcomes of the least healthy improves equity. This unfairness is implicit in our description of the DCEA case study below, and we hereafter use the term inequalities when discussing the measurement and evaluation of health inequalities.

DCEA evaluates policies on two criteria: total health gain and health inequality improvement (Asaria et al., 2016). Decision analytic modelling can be used to estimate the distribution of health benefits generated by a policy or an intervention; these are then added to estimates of the baseline distribution of health. The change in inequality is obtained by comparing the baseline distribution with the post-policy one. The effects on population health and health inequality can be represented separately on the health equity impact plane or combined analytically through health-related social welfare functions (Cookson et al., 2017).

Decision problem

The larger scale of PSIs mean they are less likely to be evaluated in an experimental comparison with a control group (such as a randomised controlled trial) and more commonly employ quasi-experimental study designs. However, conducting economic evaluations of PSIs after they have been implemented arguably limits the relevance of that evidence, as

policymakers ideally require more forward-looking (rather than historical) information. Hence, in order to better inform decision-making, economic evaluations that use retrospective evidence should identify aspects of the policy that can be realistically altered, as, for instance, population coverage or the model of service delivery.

In order to align the case study model with the timeframe of the effectiveness evidence for the PSF, we use data for 1994-5, the period before the programme was rolled out. This avoids having to disentangle trends in health in Brazil following the introduction of the PSF from the independent effect of the PSF itself.

Outcomes

Net health benefit and changes in health inequality are measured in terms of DALYs. This is a generic measure that quantifies changes in both survival and health-related quality of life. DALYs attach health-related quality of life weights, defined on a tariff and elicited through international population surveys (Salomon et al., 2015), to disease-specific health states that represent health loss. A year spent in perfect health results in 0 DALYs (no health loss), whilst a year spent with moderate chronic obstructive pulmonary disease results in 0.225 DALYs (GBD 2016 DALYs and HALE Collaborators, 2017). Health benefits are therefore expressed as DALYs averted.

Health inequalities are measured in terms of differences in lifetime DALYs (i.e. healthy life expectancy) between the 27 states in Brazil. Output from the decision model is combined with a baseline distribution of health to construct a post-policy distribution. Comparing the differences provides a means to assess the estimated change in health inequalities.

Population

The PSF, being a particular model of primary care delivery, can potentially cover the whole Brazilian general population. The recipient population under the purview of PSF teams is estimated for each state using published coverage data. This was only available by macro-region in 2000 (Ministério da Saúde, 2008); we therefore use the relative levels of coverage of the states within each region from 2007 (Departamento de Informática do SUS, 2019) to impute state coverage levels for 2000. Scenario analysis explores the impacts of implementing the PSF at full population coverage.

Comparator

Economic evaluation requires the clear identification of a comparator policy (or policies) against which an intervention is assessed. This can be unclear for PSIs: they may be imposed on a health system with large variations in standard practice, or they may have many potential formulations, each of which could be a legitimate comparator. The specific alternatives to the programme need to be considered carefully, and these could include programme tweaks or adaptations (e.g. incentives to encourage uptake).

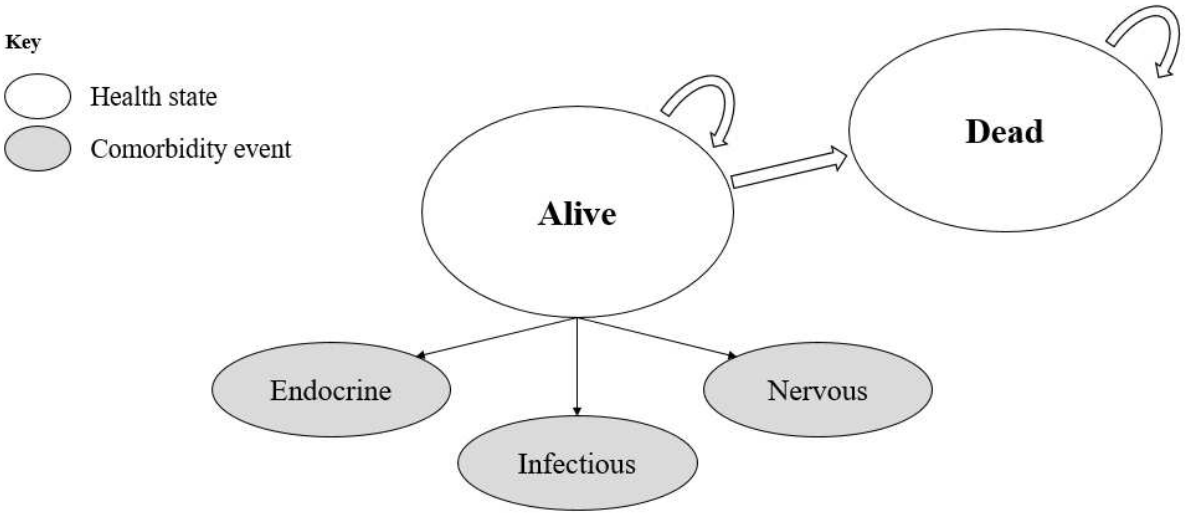
In this paper, we evaluate the PSF in comparison to the provision of primary care through health clinics and centres that were available in Brazilian municipalities without the PSF. PSF teams were introduced as replacements to the pre-existing services, rather than additions (Macinko et al., 2004). The supply and quality of primary care services varied considerably between Brazilian states and municipalities before the implementation of the PSF and could not be adequately controlled for in the impact evaluation that informs our treatment effects. The size of the health benefit generated in a region from the PSF will therefore be partially determined by what comparator system was otherwise in place.

Decision model

We developed a decision model to estimate the incremental costs and DALYs averted from implementing the PSF. The model uses a Markov structure with a lifetime time horizon, in which a cohort of individuals progresses in one-year cycles through the life course. In each cycle a proportion of the cohort dies and those alive are at risk of a range of comorbidities, determined by estimates of age-specific mortality and disease prevalence, respectively. The mortality rates reflect all potential causes of death, including those modelled as comorbidities. We therefore incorporate the comorbidities as events (rather than states) that reduce health-related quality of life only, as well as imposing health system costs. In order to estimate the heterogeneous effects of the PSF we require estimates of many different inputs for each state. These components include variables such as the baseline health and disease prevalence, treatment effects, intervention costs and opportunity costs. This is a data-intensive feature of all equity-informative evaluations. The model structure is shown in Figure 1, whilst a list of inputs and data sources are provided in Table 1.

We used evidence from an impact evaluation of the PSF to modify mortality risks and comorbidity prevalence. Cohorts using the original and modified inputs were then modelled and the difference in the outcomes were obtained to assess the incremental effect of the PSF. As the cohorts in the model are all the same age by design, we calculate population-averaged outcomes by running the model for 19 different age bands (covering ages 0 to 100). A weighted average estimate is then computed, in which the weights are the relative population density of each age group.

Figure 1: Decision model structure



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4 Table 1: Inputs and data sources for distributional cost-effectiveness analysis

Input	Description	Source	PSA Distribution
Effectiveness of PSF	Absolute changes in all-cause mortality rates by age and macro-region	Rocha and Soares (2010)	Lognormal
Baseline all-cause mortality	GBD estimates by age and state	Institute for Health Metrics and Evaluation (2019)	Beta
Baseline cause-specific mortality	DataSUS estimates of deaths from endocrine, infectious and nervous diseases by age and macro-region	Departamento de Informática do SUS (2019)	Beta
Disease prevalence	GBD estimates by age and state	Institute for Health Metrics and Evaluation (2019)	Beta
Health opportunity costs	Health system marginal productivity for both national and state-level healthcare expenditure	Ochalek, Lomas and Claxton (2018) (national), Institute for Health Metrics and Evaluation (2019) & Tesouro Nacional (2019) (state)	N/A

Input	Description	Source	PSA Distribution
Baseline healthy life expectancy	Disability-adjusted life expectancy at birth by state	Marinho et al. (2018)	Normal
Disability-adjusted life year weights	Health-related quality of life weights for the 30 largest contributors of disease burden in Brazil	GBD 2016 DALYs and HALE Collaborators (2017)	Beta

Notes:

1. PSF = Programa Saúde da Família; PSA = probabilistic sensitivity analysis
2. PSF effectiveness is shown in Figure 2. Disability-adjusted life year weights are provided in Table A1. State-specific parameters for healthy life expectancy and health opportunity costs are provided in Table A3. Mortality and disease prevalence data are available from the authors upon request.

Health-related quality of life effects were incorporated into the model using data on the 30 largest causes of DALYs in Brazil, extracted from the Global Health Data Exchange (Institute for Health Metrics and Evaluation, 2019). Six causes not related to a specific health condition (such as vehicle and other types of accidents) were removed. The remaining 24 causes, along with their associated DALY weights, are given in Table A1 (supplemental materials).

Five causes are explicitly modelled as comorbidities (diarrheal diseases, dietary iron deficiency, lower respiratory infections, meningitis and protein-energy malnutrition). These relate to infant and childhood diseases that are primarily affected by the PSF (Harris and Haines, 2010). The loss of health-related quality of life in each cycle of the model attributable to each comorbidity is equal to its age- and state-specific prevalence multiplied by the disability weight multiplied by the alive population. The 19 other causes are used to calculate the expected health-related quality of life score for those in the alive state (i.e. those without

any modelled comorbidities). This is calculated as 1 minus the prevalence multiplied by the disability weight.

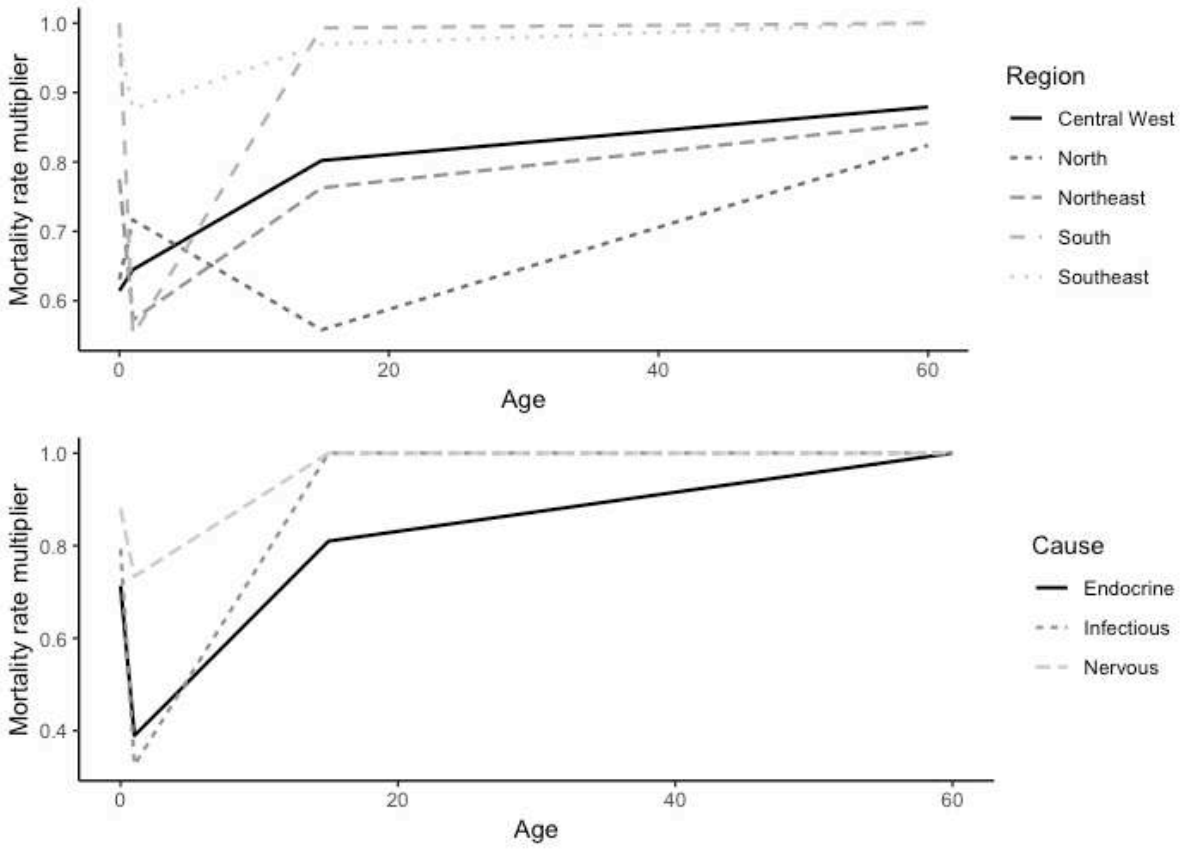
Treatment effects

Treatment effect heterogeneity is a key input in distributional economic evaluation. Crucially, this heterogeneity needs to align with the equity-relevant groups defined in the decision problem. However, the quasi-experimental methods used in impact evaluations of PSIs tend to control for equity-relevant variables in their statistical models rather than interact them with the treatment variable in order to estimate the required heterogeneity. If the estimates of heterogeneity are limited, then assumptions on the variation in treatment effect may be required. Furthermore, in order to compare the health resources used between PSIs and other interventions, the outcome used should be linkable to a generic measure of health such as the DALY.

Despite the PSF's equity-related objectives, few empirical studies have explored treatment effect heterogeneity with respect to equity-relevant characteristics. Our case study utilises one such study by Rocha and Soares (2010), which estimated absolute mortality changes attributed to the PSF by (i) age and cause of death and (ii) age and each of the five Brazilian macro-regions. The authors used a quasi-experimental, difference-in-differences approach on a sample of over 5000 Brazilian municipalities, using data for the eight years following the PSFs introduction (1995-2003). The analysis included controls for secondary care supply, education infrastructure and immunization coverage.

The results of Rocha and Soares are used to estimate the relative effects of the PSF on all-cause mortality (Marinho et al., 2018) and cause-specific mortality (Departamento de Informática do SUS, 2019). These are shown in the top and bottom panels of Figure 2, respectively. The all-cause mortality effects are used to modify the age-specific mortality risks in the model. The relative effects for each macro-region are applied to its constituent states, giving unique absolute mortality changes for each state. The cause-specific mortality changes are used as proxies with which to estimate the pure quality of life losses associated with the five modelled comorbidities. Each comorbidity is mapped to one of three broad causes analysed by Rocha and Soares: conditions of the endocrine and nervous systems and infectious diseases. This is done by applying the cause-specific relative effect to disease prevalence.

Figure 2: Relative effect of the *Programa Saúde da Família* on all-cause (top) and cause-specific (bottom) mortality



Costs and opportunity costs

Calculating the relevant costs of PSIs is also likely more complicated than in the case of standard healthcare interventions. The absence of cohort or RCT data means that the effects on resource use can be more difficult to isolate, whilst PSIs change the ways in which patients interact with the health system in the long-term, creating implications for supply and demand for services (Sutton et al., 2018). PSIs can also involve high start-up costs with large, non-marginal budget impacts (Howdon et al., 2019).

The PSF case study groups the cost impacts into direct programme costs and indirect comorbidity costs. No data on how these costs varied by state could be identified. Prices are adjusted to the year 2000 for all costs using CPI inflation rates from the International Monetary Fund's World Economic Outlook database and converted to USD (International

Monetary Fund, 2019). Comorbidity costs are extracted from a range of cost of illness and economic evaluation studies, with Brazilian estimates used where available. Within the model, the values represent the cost per annual prevalent patient and reflect the range of disease severity and treatment options across the patient population. These range from $24 for protein energy malnutrition to $15,700 for lower respiratory infections (see Table A2 in the online appendix). The costs for the latter and for diarrheal diseases are based on intervention costs for an incident case. As incidence is higher than prevalence for these conditions, we used their incidence-to-prevalence ratio to calculate the cost per prevalent patient.

The costs involved in delivering the PSF include: personnel, medicines, administration and other overheads. The average cost of these components is estimated at between $31 and $50 (Rocha and Soares, 2010). We use a midpoint of $41 as our base case figure, which correlates well with other published estimates (Filho and da Silva, 2009; Hone et al., 2017).

The total costs associated with implementing the PSF represent lost opportunities for investing the resources in alternative interventions and policies. When evaluating equity impacts, we need to know not only what these opportunity costs are, but how they are distributed between the equity-relevant groups. PSIs are more likely to be financed (i) by increasing the health budget, (ii) from multiple health budgets, or (iii) from budgets across different sectors of public expenditure. Each scenario adds complexity for understanding distributions of opportunity costs, which are an essential component of a robust economic evaluation.

We convert the total cost impacts of the PSF into health opportunity costs using empirical estimates of the marginal productivity of health resources in Brazil. As the PSF is funded from separate federal, state and municipal health budgets, we try to reflect any potential differences in the marginal productivity between states in the health opportunity costs of the programme. For the proportion of PSF and comorbidity costs covered from the federal budget, a health opportunity cost ratio of $8,047 per DALY averted was used (Ochalek et al., 2018). We make the simplifying assumption with these health opportunity costs that the forgone DALYs averted are allocated to states on a per capita basis. For the costs covered from state health expenditure, we estimate a set of state-specific ratios using methods outlined by Ochalek et al. (2019). These range from $2,483 for Maranhão to $30,476 for Amapá and are shown in Table A3 (online appendix). Within the model we assume that 61% ($25) of PSF costs and 43% of general healthcare costs are covered from the federal budget, using evidence from Filho and da Silva (2009) and Rajkumar et al. (2014), respectively. We assume that these forgone DALYs averted fall entirely within each state.

Inequality impacts

We investigate the impact of the PSF in terms of both bivariate and univariate inequalities. Bivariate inequalities analyses state health in terms of a second variable – in this case the gross regional product, a state-level indicator of socioeconomic status. Univariate inequality analysis ranks the states in terms of their health only.

We use the slope index (SII) and relative index of inequality (RII) to summarise inequalities. The SII is defined as the slope coefficient from a simple linear regression of health on the fractional ranking of the state (in terms of health or other variables) and the RII is the SII divided by mean health. The SII and RII are interpreted as the absolute and relative

difference in health when moving from the least to most healthy state, respectively. The bivariate analysis uses health benefits as the dependent variable and fractional GRP rank as the independent variable. The univariate analysis uses healthy life expectancy as the dependent variable and fractional health rank as the independent variable.

The univariate analysis compares expected inequalities with and without the PSF. The per person net health benefits for each state are added to a respective estimate of baseline health to generate a post-policy distribution of health. We take a distribution of healthy life expectancy by state from Marinho et al. (2018) to represent pre-PSF levels of health inequality. Estimates from 1990 (shown in Table A3) are used and align closely with the pre-PSF period. Using the baseline distribution therefore allows us to estimate the impact of the intervention on population health inequalities, our equity outcome of interest (Cookson et al., 2017).

Last, we use health-related social welfare functions to calculate the change in 'equally distributed equivalent health' (EDE) – a single index measure of health that combines concerns for average health improvement and univariate health inequality. The Kolm and Atkinson indices are computed to reflect absolute and relative equity concerns, respectively (Asaria et al., 2015). The change in these equity-weighted EDE DALYs averted are useful for two purposes. They can be used to evaluate potential trade-offs between inequality and population health (i.e. policies that increase both health inequality and population health or vice versa) and be compared to the total unweighted DALYs averted to get a sense of value, in terms of DALYs, of the reductions or increases in inequalities.

The Kolm and Atkinson indices include an 'inequality aversion' parameter that captures the strength of social preferences for reducing inequalities. Higher aversion results in lower EDE health. Estimation of this parameter is highly uncertain and has not been specifically elicited for the Brazilian population. For example, a review by McNamara et al. (2019) found that elicited or implied values of Atkinson inequality aversion ranged from 1 to 28.9. We therefore calculate health-related social welfare across a range of inequality aversion levels: an Atkinson ε of 0 to 30 and a Kolm α of 0 to 0.5. Further details on the use and interpretation of these functions within health economic evaluation can be found in Asaria et al. (2015).

Uncertainty

Uncertainty in our results is estimated through probabilistic sensitivity analysis. This process uses Monte Carlo simulation to randomly draw model input values from their respective probability distribution and re-run the model many times to obtain a distribution of outcomes. Five sets of inputs are varied over 3,000 simulations: mortality rates, comorbidity prevalence, disability weights, PSF effectiveness and baseline healthy life expectancy. Two further scenarios are modelled: one in which we assume that the PSF does not modify comorbidity prevalence (only mortality), and a second in which there is full population coverage. Deterministic sensitivity analysis is also conducted on the PSF intervention cost.

Results

Population health effect

The PSF is estimated to improve health in all states. The average cost-per-DALY averted across all states was $2640 (95% confidence interval [CI] $2136 to $3220). The outputs from

the cost-effectiveness model are shown in Table 2 and Figure A1. The largest average health gains are seen in Rondônia, with an improvement of 0.649 DALYs averted per person. The lowest are found in Sao Paulo, with an average of 0.123 DALYs averted. Using the estimated coverage levels for each state, this translated into 5.29 million DALYs averted in the Brazilian population.

Table 2: Per recipient health impacts of the *Programa Saúde da Família* by state

State	Life years	DALYs averted	Health opportunity costs	ICER	Net health benefit
Acre	0.832 (0.328)	0.622 (0.196)	0.088 (0.006)	£685	0.533 (0.192)
Alagoas	0.59 (0.138)	0.484 (0.088)	0.167 (0.01)	£349	0.316 (0.087)
Amapá	0.748 (0.304)	0.576 (0.178)	0.078 (0.005)	£1,336	0.498 (0.175)
Amazonas	0.73 (0.313)	0.571 (0.182)	0.09 (0.006)	£1,158	0.481 (0.179)
Bahia	0.531 (0.132)	0.4 (0.079)	0.14 (0.007)	£493	0.26 (0.077)
Ceará	0.491 (0.127)	0.392 (0.075)	0.15 (0.009)	£475	0.242 (0.074)
Distrito Federal	0.483 (0.167)	0.4 (0.107)	0.075 (0.003)	£784	0.325 (0.106)
Espírito Santo	0.054 (0.054)	0.126 (0.041)	0.082 (0.004)	£4,820	0.043 (0.042)
Goiás	0.497 (0.173)	0.396 (0.108)	0.106 (0.005)	£806	0.291 (0.107)
Maranhão	0.493 (0.121)	0.407 (0.075)	0.198 (0.011)	£445	0.209 (0.074)
Mato Grosso	0.467 (0.166)	0.393 (0.105)	0.102 (0.006)	£1,876	0.29 (0.103)
Mato Grosso do Sul	0.497 (0.169)	0.405 (0.106)	0.087 (0.004)	£853	0.318 (0.105)
Minas Gerais	0.047 (0.052)	0.125 (0.039)	0.086 (0.004)	£9,331	0.039 (0.04)
Pará	0.714 (0.31)	0.541 (0.179)	0.139 (0.01)	£932	0.403 (0.173)
Paraíba	0.52 (0.133)	0.429 (0.081)	0.136 (0.009)	£405	0.294 (0.08)
Paraná	0.069 (0.057)	0.159 (0.044)	0.098 (0.006)	£2,425	0.06 (0.046)
Pernambuco	0.609 (0.148)	0.48 (0.092)	0.149 (0.008)	£363	0.331 (0.09)
Piauí	0.459 (0.121)	0.383 (0.073)	0.13 (0.008)	£488	0.253 (0.073)

Rio de Janeiro	0.062 (0.061)	0.133 (0.044)	0.091 (0.004)	£16,772	0.042 (0.045)
Rio Grande do Norte	0.49 (0.127)	0.399 (0.077)	0.135 (0.007)	£478	0.264 (0.076)
Rio Grande do Sul	0.062 (0.058)	0.121 (0.039)	0.084 (0.003)	£4,932	0.037 (0.04)
Rondônia	0.865 (0.34)	0.649 (0.202)	0.098 (0.007)	£731	0.55 (0.198)
Roraima	0.834 (0.332)	0.621 (0.2)	0.088 (0.005)	£4,780	0.533 (0.196)
Santa Catarina	0.068 (0.057)	0.143 (0.042)	0.086 (0.005)	£3,028	0.057 (0.044)
São Paolo	0.054 (0.054)	0.123 (0.041)	0.081 (0.004)	£13,770	0.042 (0.041)
Sergipe	0.574 (0.139)	0.459 (0.086)	0.107 (0.006)	£384	0.352 (0.085)
Tocantins	0.694 (0.305)	0.537 (0.179)	0.107 (0.007)	£906	0.43 (0.175)

Notes:

1. PSF = Programa Saúde da Família; DALYs = Disability-adjusted life years; ICER = Incremental cost-effectiveness ratio
2. ICERs are relative to the pre-PSF primary care system and are calculated from the sum of costs at the state and federal health budget. These have different rates of health opportunity cost that are not reflected in the ICER, but are in net health benefit.
3. Health opportunity costs and net health benefits are both expressed in terms of DALYs averted
4. Standard errors in parenthesis

Distributional effects

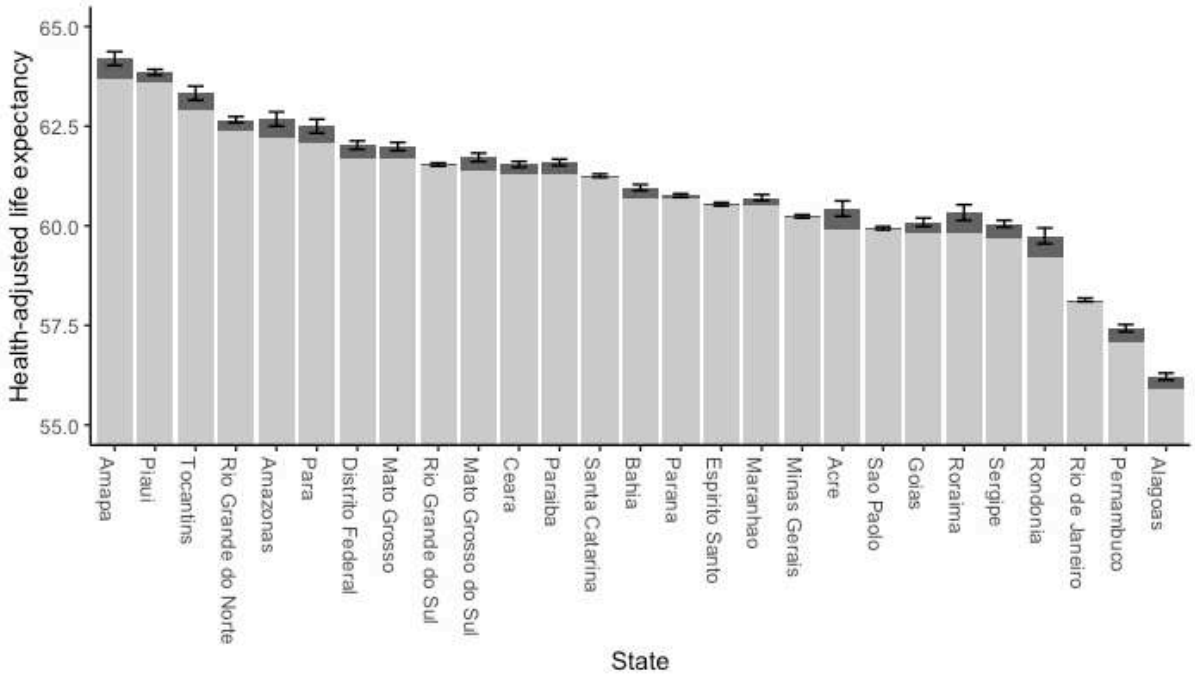
Bivariate inequality analysis found that health benefits were greater for those states with lower average incomes. The SII indicates that moving from the lowest to highest GRP was associated with a reduction of 0.24 DALYs averted per person (95% CI -0.347 to -0.135). The translated into an RII of -1.583 (95% CI -2.444 to -0.845), interpreted as the lowest GRP state having health gains 2.5 times greater than the highest GRP state.

The univariate inequality analysis found that the health impact of the PSF was not correlated with state-level healthy life expectancy. Several of the states with the highest pre-PSF healthy life expectancy, including Amapá, Amazonas and Toncantins, are those with amongst

average net health benefit. Similarly, states such as Rio de Janeiro and São Paolo, which have low baseline health, also have lower net health gains. This relationship is shown in

Figure 3. The reductions in SII and RII were both smaller than 0.001 and neither were statistically significant.

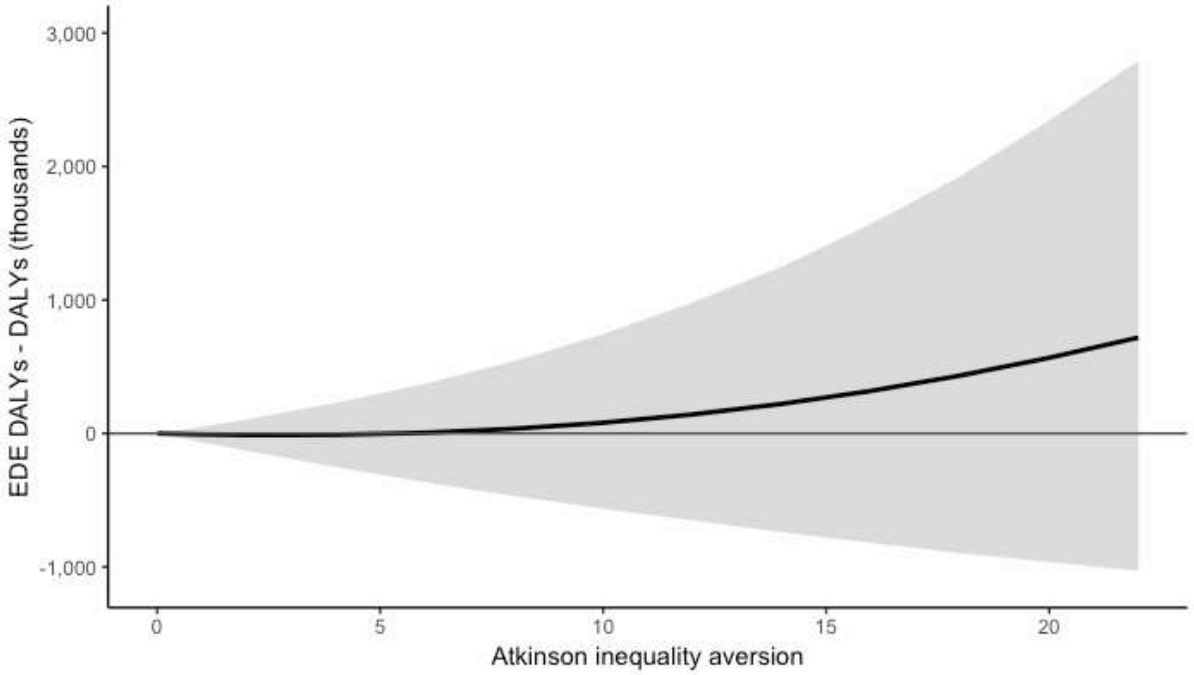
Figure 3: Univariate inequalities in health for Brazilian states: baseline healthy life expectancy (light grey bars) and net health benefits from the *Programa Saúde da Família* (dark grey bars)



Health-related social welfare indices combining average population health and univariate health inequality were improved by the PSF across the range of tested inequality aversion parameter values. The welfare change attributable to inequality impacts is relatively small, even at high levels of inequality aversion. This is summarised by the difference between

DALYs averted and EDE DALYs averted and is shown in Figure 4. At an Atkinson ε of 10, for example, the inequality benefit equates to 80,000 EDE DALYs, approximately 0.15% of the total welfare change.

Figure 4: Difference between total DALYs averted and total EDE DALYs averted by the *Programa Saúde da Família* across Atkinson inequality aversion parameter levels



Notes:

1. EDE = equally distributed equivalent; DALY = disability-adjusted life year.
2. When the difference is positive, the social value of the inequality impact of the PSF is positive.
3. Shaded grey area indicates the 95% confidence interval.

Uncertainty

The probabilistic analysis estimated the 95% CI for the total health effect of the PSF was 3.92 million to 6.75 million DALYs averted. However, the probability of the PSF generating positive net health benefits was over 80% for all states.

The uncertainty around the inequality impacts of the PSF was noticeably higher and increased with the level of inequality aversion: 95% CIs for EDE DALYs were 3.91 million to 6.73 million for ε=2 and 3.83 million to 8.18 million for ε=20. The probability that the inequality impacts were socially beneficial (i.e. that EDE DALYs averted were greater than DALYs averted) was higher when inequality aversion was greater, ranging from 41% when ε=0.25 to 72% for ε=20 (see Figure 3).

The PSF produced positive net health benefits for all states across the identified range of intervention costs (between $30 and $50 per person), shown in Figure A2. The two further scenario analyses are shown in Figure A4. Net health benefits remained positive for 21 states when only the reductions in mortality are included. The six states with negative impacts under this scenario were all from the South and Southeast macro-regions. Lastly, moving from expected to full coverage reduced per person net benefits from 0.189 to 0.156 and increased health inequalities (an SII increase of 0.0398).

Discussion

Whilst methodological advances have been made in the economic evaluation of PSIs on one hand and in equity-informative economic evaluation on the other hand, this paper highlights the numerous complexities that arise when combining them within a single analysis. Our case study DCEA evaluated the impact of the PSF on geographical health inequalities in Brazil, accounting for variations in PSF effectiveness and baseline levels of health. However, we required a range of assumptions relating to the decision problem, treatment effects, costs and health opportunity costs.

Case study model

Our results indicate that the PSF has increased overall population health in Brazil, with greater estimated net benefits found in states with lower average incomes. We found considerable geographical variation in net benefits; per person DALYs averted in Rondônia (0.865) were 16 times greater than those for São Paolo (0.054). However, inequality measures indicate that between-state inequalities did not change substantially.

We adopted conservative modelling assumptions where possible in order to avoid overstating the impact of the PSF. Out of all possible health-related quality of life effects, we were able to capture five comorbidities (representing 15% of the overall DALY burden for Brazil), hence omitting potential benefits from averting or mitigating other conditions. We also used the absolute cost of PSF teams rather than an incremental cost that accounts for the counterfactual provision of a comparator programme, thereby likely underestimating the cost-effectiveness of the PSF. Finally, the impact evidence defined municipality-level PSF coverage as a binary variable. However, PSF coverage in many municipalities will not be 100%, meaning that the mortality effect of the PSF will likely be underestimated.

Several limitations in the analysis should also be noted. Comorbidity costs are taken from studies conducted between 2012 and 2018, a period in which per capita healthcare expenditure will likely have been higher than in our baseline year of 1994. Even after accounting for inflation, this could overestimate the cost savings and net benefits associated with the PSF. We also lack information on the dynamic effects of the PSF, with respect to the demand for, or supply of, health services. The health benefits estimated by Rocha and Soares (2010), for example, are likely a combination of the direct benefits from the PSF (such as behaviour change or vaccination) and indirect benefits from being referred to other types of

health services. Indirect effects also impose additional costs on the system and may require increased investment in infrastructure. These could not be captured in the model, thereby inflating the cost-effectiveness of the PSF.

Distributional economic evaluation of PSIs

Several issues that we faced developing our decision model will be more generalisable to other distributional evaluations of PSIs. The most notable of these is the use of quasi-experimental treatment effectiveness evidence, which is likely to be main source of evidence for PSIs with more complex implementation and wider health system effects. Researchers need to consider how such evidence can be useful for informing contemporaneous decisions if it relates to PSIs that have already been implemented. This could be done by evaluating the impacts of tweaks to the intervention, such as improving coverage for those with poor access to services. Availability of evidence will also restrict the type of distributional evaluation approaches that can be undertaken. In our analysis, we could not implement other approaches (particularly ECEA) to model equity-relevant outcomes such as healthcare access or FRP (Bastos et al., 2017), as we could not identify evidence on how the PSF impacted them across sociodemographic or geographic groups.

Treatment effect heterogeneity is another key evidence requirement that can be challenging to identify. This is because we need quasi-experimental studies that characterise heterogeneity in terms of policy relevant subgroups (e.g. socioeconomic or geographic) that can then also be linked to downstream outcomes (e.g. mortality risk). Despite the impact evidence used in our case study characterising treatment effect heterogeneity in terms of several different variables (age, cause and macro-region), we still required further assumptions to model health-related quality of life effects and state-specific effects.

Furthermore, because the impact evidence was based on a municipality-level analysis, our results do not reflect the potentially targeted implementation of PSF teams within municipalities to areas with deprived populations or very limited pre-existing healthcare facilities.

By estimating state-specific health opportunity costs, our analysis partially accounted for the fact that state-level health expenditures generate opportunity costs may differ from those of the federal budget. However, we were not required to define any social distribution of opportunity costs because of our focus on geographical inequalities only. Evaluations analysing sociodemographic inequalities would require further analysis or assumptions about the opportunity cost distribution.

Conclusion

PSIs represent a significant use of health system resources and have the potential to generate large impacts on population health and health equity. Distributional economic evaluation can produce evidence on PSIs but imposes additional data requirements that may limit its usefulness. The validity and quality of future research will therefore be dependent upon the availability of quasi-experimental impact evidence that can inform contemporaneous health policy decisions and show how different equity-relevant subgroups are affected.

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