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Research paper

The lifetime costs of perinatal depression and anxiety in Brazil

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ABSTRACT

Background: Each year, an estimated 860,000 Brazilian women experience depression and anxiety perinatally. Despite well-known devastating impacts of these conditions on mothers and children, they remain neglected in low- and middle-income countries. Knowing the costs of untreated perinatal depression and anxiety can inform decision-making.

Methods: Simulation modelling is used to examine lifetime costs of perinatal depression and anxiety for a hypothetical cohort of women and their children, followed until children are aged 40 years. Costs are measured from a societal perspective, including healthcare expenditure, productivity and health-related quality of life losses; 2017 data are taken from country-specific sources. Present values are calculated using a discount rate of 3 %.

Results: Lifetime cost of perinatal depression and anxiety in Brazil are USD 4.86 billion or R$ 26.16 billion, including costs linked to poorer quality of life (USD 2.65 billion), productivity loss (USD 2.16 billion) and hospital care (USD 0.05 billion). When the costs associated with maternal suicide are included, total costs increase to USD 4.93 billion.

Limitations: Several costs could not be included in the analysis because of a lack of data. The study is reliant of longitudinal data on associations between perinatal depression and anxiety and impacts on mothers and children. Therefore, no causality can be inferred.

Conclusion: Our findings illustrate the economic rationale for investment in this area. This is the first study that estimates the costs of perinatal mental health problems in a low- or middle-income country setting.

1. Background

Maternal depression and anxiety during the perinatal period, defined as the period from start of pregnancy to one year postpartum, are highly common globally, with higher rates in lower-and middle-income countries compared with high-income countries (Fisher et al., 2012; Woody et al., 2017). In Brazil, studies conducted before the Covid-19 pandemic commonly show prevalence rates for maternal perinatal depression or anxiety of 15 to 30 % (Coll et al., 2017; Manzolli et al., 2010; Silva et al., 2012; Silva et al., 2019; Soares et al., 2009; Tavares et al., 2012; Theme Filha et al., 2016). During the pandemic, rates appear to have increased to much higher levels, with findings from one large study conducted in Rio Grande RS reporting that 41 % women experienced moderate to severe stress, 29 % probable depression and 26 % probable generalised anxiety disorder (Loret de Mola et al., 2021). Whilst no national data are yet available on the impact of the pandemic on maternal suicide, data from before the pandemic show that 10 % to 13 % of women are at suicidal risk during the perinatal period (Pinheiro et al., 2012; Tavares et al., 2012). Since many of the risk factors for mental health problems (e.g., financial difficulties, unemployment, trauma, bereavement, social isolation, domestic violence) (Faisal-Cury et al., 2021; Lobato et al., 2011), are likely to persist even after the end of the pandemic, it is also likely that perinatal depression and anxiety, without appropriate actions, will remain at high levels.

Perinatal depression and anxiety not only have substantial adverse impacts on mothers – such as in the form of human suffering, physical

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illness, reduced quality of life, relationship problems, risky behaviours and suicidal thoughts (Howard and Khalifeh, 2020; Slomian et al., 2019) - but also on their children. Considerable global evidence shows the impact of these conditions on the infant and child, in the form of preterm birth, low birth weight, reduced growth, poorer physical and mental health, and developmental, including intellectual, problems (Dadi et al., 2020; Grigoriadis et al., 2013; Grote et al., 2010; Jarde et al., 2016; Stein et al., 2014). Maternal depression is the leading risk factor for childhood stunting, with a recent study suggesting that, across 137 low- and middle-income countries, 3.2 million cases are attributable to maternal depression (Smith Fawzi et al., 2019). In Brazil, evidence suggests a link between depression in pregnancy and low birth weight (Menezes et al., 2012; Netsi et al., 2020), leading to increased use of intensive care in the short-term (Menezes et al., 2012), but also to longer-term attention problems (Netsi et al., 2020). (The latter has been found more robustly in girls.) Other national studies have found that children of women with persistent depression after the perinatal period are more likely to later develop mental health problems (Matijasevich et al., 2015), become victims to bullying (Azeredo et al., 2017) and have lower socioemotional competencies (Maruyama et al., 2020). In addition, evidence shows a relationship between mothers' social anxiety disorders during the perinatal period and child language development (Castelli et al., 2015) as well as between chronic postnatal depression and child sleep disorders (Pinheiro et al., 2011). A recent study analysing data from the city of Pelotas found that maternal depression ante- and postnatally is linked to children's hospital admissions (Jacques et al., 2021).

Mechanisms underlying associations between perinatal mental health problems and adverse child outcomes are complex but include biological or bio-chemical together with psychological processes, as well as genetic, social, and environmental factors (Stein et al., 2014). For example, increased cortisol levels in mothers caused by increased stress are transmitted to the foetus during pregnancy (Glover et al., 2018), whilst in the postnatal period, mothers' caring roles can be negatively affected, which is reflected in lower maternal sensitivity, mother-infant attachment quality, difficulties in breast feeding, all of which have been linked to both short- and long-term consequences for children's health and development (Stein et al., 2014).

Globally, most maternal mental health problems remain untreated. In Brazil, data from the 2013 National Survey showed that 82 % of women with perinatal depression remained unidentified (Faisal-Cury et al., 2021). Whilst the urgent need to address maternal mental health problems as one of the most important risk factors for early child development problems has been advocated by international organisations such as the World Health Organization (World Health Organization, 2008), this has, in most low- or middle-income countries, not led to adequate policies or investments. In Brazil, whilst important progress has been made over recent decades to support maternal and child health care – reflected, for example, in yearly infant mortality reductions of 5 % and child stunting reductions by 30 % (Victora et al., 2011) – such efforts have focused on physical rather than mental health.

The costs of untreated perinatal depression and anxiety linked to human suffering and productivity loss are likely to be substantial. For example, evidence from the United Kingdom suggests that the societal costs of perinatal depression and anxiety are as high as £6.6 billion for each years' births (Bauer et al., 2016b). This is equivalent to just under £1 billion per 100,000 births. Two thirds of the costs stem from the adverse impact of these conditions on children. Costs are likely to be different in low- and middle-income countries. For example, investments into most types of public sector support to address the impact of perinatal depression and anxiety, some of which would be part of the costs included in a cost-of-illness study, are much lower. At the same time, those investments act as buffers for some of the negative long-term impacts of these conditions on human suffering and productivity.

Cost-of-illness or cost-impact analyses, which highlight the economic impacts of a health problem at the national population level, can inform policy makers and influencers about the importance of intervening. They can also provide some indication of the potential economic benefits of investing to address the problem. The aim of this study is to estimate the lifetime cost of perinatal depression and anxiety in Brazil by considering the long-term impacts on both mothers and children.

2. Method

2.1. General approach

We use simulation modelling techniques. Costs relate to a hypothetical cohort of women or girls aged 15 to 38 with perinatal depression and/or anxiety giving birth in 2017 and the children they give birth to in the same year, who are then followed over time: for women ten years and for children 40 years. The ten-year period for women reflects the chronic course of perinatal mental health problems for some women. For children, the time horizon of 40 years reflects that this period is likely to capture most economic impacts during adulthood. (Even though the cohort includes girls, in the rest of the paper we refer to women or mothers to describe the cohort.) In our approach for valuing costs, we follow recommendations by the World Health Organization (WHO) (WHO, 2003) to include costs from the perspectives of government as well as wider society. This means that, in addition to valuing costs for public sector services (in our study this refers to healthcare), we value income losses as well as losses in quantity and quality of life, measured in the form of disability-adjusted life years (DALYs). The outcomes, types of costs and data sources included in the modelling are shown in Table 1. Since we model costs as they would occur in the future, we calculate what those costs would be worth in the present year (here: 2017) using a discount rate of 3 % for DALYs, income losses and healthcare costs. The year 2017 is chosen as present year because this is the latest year for which most statistical data about women and children were available.

For the modelling, we use published data from various sources, including peer-reviewed studies and reports from national and international governmental and non-governmental organisations including the Brazilian government, World Health Organization and World Bank. Data refer to Brazil and are taken from national or regional data sources

Table 1
Types of costs included in the analysis, and their data sources.

Outcome	Types of cost	Data source for costs
Maternal mental illness during perinatal period (antenatal + postnatal depression/anxiety/ suicide)	Disability Adjusted Life Years (valued in GDP)	Global Burden of Disease; disability weights
	Employment/income (valued in GDP)	Data on absenteeism and presenteeism for people with mental illness
Maternal mental illness subsequent episodes/ chronic development of depression and anxiety	Disability Adjusted Life Years (valued in GDP)	Global Burden of Disease; disability weights
	Employment/income (valued in GDP)	Data on absenteeism and presenteeism for people with mental illness
Child's low birth weight (first year of life)	Disability Adjusted Life Years (valued in GDP)	Global Burden of Disease; disability weights
	Neonatal intensive care (valued in public healthcare expenditure)	Unit cost for neonatal care and mother-infant accommodation per child born with low birth weight
Child hospitalisation	Hospital admission and stay for respiratory infections (valued in public healthcare expenditure)	Unit cost for hospitalisation due to respiratory infections, among infants
Child attention problem linked to low birth weight (after first year of life, girls only)	Disability Adjusted Life Years (valued in GDP)	Global Burden of Disease; disability weights
Child internalising and externalising problems	Disability Adjusted Life Years (valued in GDP)	Global Burden of Disease; disability weights

where those are available. A key data source for the impact of perinatal depression and anxiety on child outcomes is the 2004 Pelotas birth cohort study. The study follows >3000 mothers and their children over time, starting from pregnancy until 15 years after birth and collecting information about mother's depression and anxiety during the postnatal period and various infant and child outcomes (Barros et al., 2006). If the relevant data were not available from national or regional sources, we considered international evidence. For example, disability weights are taken from international sources, as there are currently no national disability weights. All parameters, values and data source sources are shown in Table 2. The following sections provide details about the analysis.

2.2. Cohort of women with maternal mental health problems

The number of women who would develop depression and/or anxiety during the perinatal period and the number of children affected by those conditions are estimated. For this, the number of mothers who become pregnant are derived from live birth data available from national statistics. Women who are giving still births are added to the number of live births to estimate the number of women who become pregnant. For simplicity, no adjustments are made to reflect multiple births.

Next, prevalence data for perinatal depression and anxiety are applied to these numbers. Following a conservative approach, the model only includes depression and anxiety (distinguished into ante- and postnatal periods) as mental health conditions for which there are sufficiently robust prevalence data. Because data on prevalence varies strongly between studies in different settings, estimates are chosen that reflect lower values. For antenatal depression, a rate of 15 % is assumed to reflect the prevalence of the condition, either in a moderate or severe state. For postnatal depression, a rate of 20 % is assumed to reflect moderate or severe conditions. The latter is the lower value of a range identified in the Pelotas study (Santos et al., 2007).

For an accurate estimation of disease burden, we seek to distinguish between severities of depression and anxiety. However, scarce data on the severity of these conditions in low- and middle-income countries prevents an exact estimation of women with mild, moderate or severe conditions. And whilst severity distributions from high-income countries suggest that of people with depression, about 8 % have severe depression, this is likely to be an underestimate in low- and middle-income countries (Burstein et al., 2015). Therefore, since one of the authors of this research is part of the Pelotas birth cohort study team, we re-ran the analysis on this data set using a cut-off score on the Edinburgh Postnatal Depression Scale of 12 for probable moderate to severe depression and of 19 for probable severe depression (MGH Centre for Women's Mental Health, 2016). We find that the proportion of women scoring probable severe depression among those scoring probable moderate or severe depression is about 20 %. We use this proportion in our analysis.

For the prevalence of anxiety, an adjusted prevalence is used in the model reflecting the number of women who have anxiety without co-existing depression. We derive this by subtracting the prevalence of co-morbid depression and anxiety (taken from international data), which suggests that one third of women with depression have a co-existing anxiety disorder (Falah-Hassani et al., 2017), from the prevalence for antenatal anxiety (8.5 %) and postnatal anxiety (17 %) (de Matos et al., 2018; Tavares et al., 2012). For simplicity and because of a lack of data it is assumed that this proportion of women with anxiety have a moderate illness.

The number of women with a persistent development of perinatal depression or anxiety is modelled based on data from three national studies (Jacques et al., 2020; Matijasevich et al., 2015; Santos et al., 2010), which suggest that about 5 % of women with maternal depression during the perinatal period are consistently chronic or highly depressed at various follow-up points (the latest follow-up point is 6

Table 2
Parameters, values, and data sources for the modelling.

Parameter	Value	Data source and details
Model cohort (mothers)		
Number of live births (in 2017)	2,867,732	Brazilian Institute of Geography and Statistics. Births and Deaths. 1984–2018[a]
Probability of still birth	0.86 %	Still birth rate of 8.6 per 1000 births (Lawn et al., 2016)
Number of women in pregnancy before considering mortality during pregnancy	2,892,394	Derived from above: 2,867,732 + 24,663
Number of women dying from maternal death (i.e. pregnancy related)	1721	Derived from maternal mortality of 60 per 100,000 live births (in 2017), and no. of live births
Proportions of women dying from maternal (pregnancy-related) death, antenatal vs. postpartum	Antenatal: 15 % Intra/ postpartum: 85 %	Kassebaum et al. (2014), Table 2 Global and regional maternal deaths in 2013 by cause for Tropical Latin America, by cause (Kassebaum et al., 2014)
Number of women during from maternal (pregnancy-related) death during pregnancy	258	Derived from above: 1721 * 0.15
Annual probability of death (women aged 15 to 39)	0.0007	IHME GBD Life Tables 2017[b]
Number of women dying from other causes during pregnancy	1519	Derived from average mortality probability of women 15–39 years for 9 months period applied to number of live and still births: 0.0007 * (9/12) * 2,892,394
Number of women alive during whole pregnancy	2,890,619	2,867,732 + 24,663
Number of women dying from pregnancy-related causes intra- or postpartum	1463	Derived from above: 1721 * 0.85
Number of women dying from other causes during first year postpartum	2007	Derived from average mortality probability of women 15–39 years for 12 months period applied to number of live births: 0.0007 * 2,867,732
Number women alive during postpartum period	2,864,262	Derived from above: 2,867,732-1463-2007
Proportion of women with perinatal mental health problems and duration of problems		
Antenatal depression (moderate + severe)	15 %	Estimated based on: Gelaye et al. (2016); Coll et al. (2017); Pinheiro et al. (2012)
Postnatal depression (moderate + severe)	20 %	Estimated based on: Gelaye et al. (2016); Theme Filha et al. (2016); Correa et al. (2016); de Matos et al. (2018); Silva et al. (2012); Tavares et al. (2012)
Distribution ante- or postnatal depression moderate vs. severe	Moderate: 80 % Severe: 20 %	Own calculations from 2004 Pelotas study dataset; probable moderate depression was defined by a EPDS score of between 13 and 19; probable severe depression was defined by a EPDS score > 19
Antenatal anxiety	8.5 %	Derived; de Matos et al. (2018)
Postnatal anxiety	17.4 %	Derived; Tavares et al. (2012)
Prop. cause suicide in relation to all-cause mortality (perinatal period)	0.0031 %	Suicide mortality rate among women of 3.1 per 100,000; World Bank[c]
Average duration of perinatal mental health problems (in years)	0.25	Dutch study (Spijker et al., 2002) – similar values

(*continued on next page*)

Table 2 (*continued*)

Parameter	Value	Data source and details
		suggested by Garman et al. (2019) for South Africa
Proportion of women with chronic development of postnatal depression or anxiety	5 %	Derived; Santos et al. (2010); Jacques et al. (2020); Matijasevich et al. (2015)
Disability weights for mental health problems, DALY value		
Depression (moderate)	0.396	Global Burden of Disease 2013[d]
Depression (severe)	0.658	As above
Anxiety (any severity)	0.133	As above
Unit costs		
Value assigned to Disability Adjusted Life Year (DALY)	4965	Based on: GDP per capita, in 2017, USD from World Bank[e]; weight of 0.5 from Chisholm et al. (2016)
Lost productivity due to absenteeism (hours per year)	Anxiety: 31 Depression: 33 Mental disorder (any): 30	From estimates by: Andrade et al. (2013); Franca (2014); Baptista et al. (2019)
Lost productivity due to presenteeism (hours per year)	Anxiety: 60.5 Depression: 79.1 Mental disorder (any): 34	As above
Women's income, in 2017, USD	3864	National government data[f]
Men's income, in 2017, USD	5051	As above
Hours worked per year	1914	As above
Model cohort (children)		
Number live births	2,867,732	Brazilian Institute of Geography and Statistics. Births and Deaths. 1984–2018[g]
Annual probability of death	0.003 (1st year) to 0.008 (40th year)	IHME GBD Life Tables 2017[h]
Proportion children exposed to perinatal mental health problems		
Antenatal depression	15 %	Prevalence data above
Chronic postnatal depression or anxiety	5 %	Prevalence data above
Prevalence of child problems		
Low birth weight	10 %	Blencowe et al. (2019); population data for State of Rio Grande do Sul: 9.5 % in 2008 (DATASUS); 10 % stated in Menezes et al. (2012)
Attention problems	5 %	Arruda et al. (2012)
Internalising problems	9 %	Matijasevich et al. (2015)
Externalising problems	4 %	Matijasevich et al. (2015)
Risk difference for child problems in excess due to exposure to antenatal depression		
Low birth weight	9 %	Derived from Relative Risk of 1.9; based on odds ratio of 1.21 in Netsi et al. (2020) and prevalence of 10 % in unexposed group
Attention problems (girls)	1.9 %	Derived from relative risk of 1.37 in Murray et al. (2015); and prevalence of 5 % in unexposed group in
Risk difference for child problems in excess due to exposure to chronic postnatal depression		
Internalising problems	31.5 %	Derived from relative risk of 4.5 (adjusted odds ratio 6.9); and prevalence of 9 % in unexposed group
Externalising problems	31.6 %	Derived from relative risk of 8.9 (adjusted odds ratio of 8.9); and prevalence of 4 % in unexposed group
DALY per infant born low birth weight during first year		
	6.8	Derived from: DALYs in Brazil for babies born with low birth weight: 2,000,000[i]; number of live births in 2017: 2,867,732; prop. born with low birth weight: 10 %
Disability weights for child problems		
Attention problems	0.045	Global Burden of Disease 2013[i]; refers to ADHD
Internalising problems	0.265	Global Burden of Disease 2013[i]; refers to weighted (combined) estimate of anxiety disorder and depression of moderate strengths 0.5 * 0.133 + 0.5 * 0.396 = 0.265
Externalising problems	0.241	Global Burden of Disease 2013[i]; refers to conduct disorder
Unit costs		
Hospital treatment and accommodation cost per stay for baby born with low birth weight, in USD	845	From Menezes et al. (2012); based on average stay in neonatal intensive care unit of 13 days and average stay in accommodation ward or nursery of 15 days; and unit costs of USD 55 for intensive care and of 9 for nursery
Hospital cost for children admitted due to respiratory disease, in USD	311	Derived from Ministry of Health Information website[j]; refers to national average costs for hospital stay due to respiratory diseases (ICD-10 Chapter 10) among children < 1 years and average stay of 6.6 days

[a] https://economy.com/brazil/births.
[b] https://cloud.ihme.washington.edu/index.php/s/2JLHyPXCnZQyd9Q?path=%2FLife%20Tables.
[c] https://data.worldbank.org/indicator/SH.STA.SUIC.FE.P5?locations=BR.
[d] https://www.thelancet.com/action/showFullTableHTML?isHtml=true&tableId=tbl2&pii=S2214-109X%2815%2900069-8.
[e] https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=BR.
[f] https://agenciadenoticias.ibge.gov.br/agencia-sala-de-imprensa/2013-agencia-de-noticias/releases/20232-estatisticas-de-genero-responsabilidade-por-afazeres-afeta-insercao-das-mulheres-no-mercado-de-trabalho.
[g] https://economy.com/brazil/births.
[h] https://cloud.ihme.washington.edu/index.php/s/2JLHyPXCnZQyd9Q?path=%2FLife%20Tables.
[i] http://ghdx.healthdata.org/gbd-results-tool?params=gbd-api-2019-permalink/af537fd2baafa74dc0e80b6e9c7df2d8.
[j] http://tabnet.datasus.gov.br/cgi/tabcgi/exe?sih/cnv/niuf.def.

years after birth). Even though data refer to women with depression, the same proportion is assumed for women with anxiety. We assume in the model that, even for those women with persistent problems, there is a recovery from the initial episode. Therefore, we model a yearly reduction of women who have depression or anxiety following an approach used in our previous cost study in the UK (Bauer et al., 2016b), which assumes a linear remission over the course of ten years.

To derive numbers of mothers in the cohort of women alive each year, the number of women is reduced by a proportion of women who are assumed to die from other causes than maternal mental illness

during the perinatal period. For this, we use age- and gender-specific mortality data from national statistics. For the probability of death during the perinatal period we aggregate the additional risk for women to die from pregnancy- and maternity-related causes to general mortality data.

2.3. Cohort of children with adverse outcomes linked to maternal mental health problems

The number of children who develop adverse outcomes linked to their exposure to maternal depression is estimated. For this, the number of children affected by ante- or postnatal depression is multiplied by the additional risk that children will develop adverse outcomes linked to perinatal depression from birth onwards. The additional risk is derived from studies that measure the effects of perinatal mental health problems, and trajectories of these problems, on children (Matijasevich et al., 2015; Menezes et al., 2012; Netsi et al., 2020). Specifically, we consider evidence for the following adverse child outcomes: low birth weight linked to antenatal depression, subsequent attention problems in girls linked to low birth weight and internalising and externalising problems for girls and boys linked to persistent depression after the perinatal period.

Based on the proportion of children exposed to antenatal depression, the additional number of children born with low birth weight linked to antenatal depression is calculated using the most conservative value from the literature (Netsi et al., 2020). Next, to estimate the number of children who subsequently develop attention problems, we apply the additional risk that a child born with low birth weight develops attention problems (Netsi et al., 2020). This figure is applied to half of the cohort of children since the evidence is only strong for girls. Then, based on the proportion of children exposed to persistent depression, the excess number of children developing internalising or externalising problems is calculated using data from a longitudinal study, which measured the association between different trajectories of postnatal depression and child psychiatric disorders (Matijasevich et al., 2015).

As for mothers, annual mortality rates are applied to the cohort of children with adverse outcomes to adjust for the proportion children who die every year from other causes than perinatal mental illness.

2.4. Assigning costs to adverse consequences for mothers and children

First, for estimating costs of health impacts, disability weights are assigned to mothers' mental health problems and children's adverse consequences. Disability weights, taken from the Global Burden of Disease study (Salomon et al., 2015), measure the magnitude of health loss associated with specific health outcomes and are used to calculate years lived with disability. DALYs are transformed into monetary values (=costs) by attaching a threshold based on a proportion of per capita income of 0.5 (typically per capital gross domestic product; GDP). This approach is used in the World Health Organization's *Choosing Interventions that are Cost–Effective (WHO-CHOICE)* project and applied in several cost studies (Chisholm et al., 2016). For GDP per capita data we use the most recent World Bank estimates (https://data.worldbank.org), which include the impact of the COVID-19 pandemic on GDP in 2020. For simplicity, and to reflect an uncertain outlook for economic recovery, we apply 2020 GDP values for all subsequent years.

2.4.1. Costing adverse impacts on mothers

Economic impacts for mothers with mental health problems occur in the form of losses in quantity and quality of life (measured in DALYs) and in productivity during and – for the proportion of women with persistent problems – after the perinatal period. To measure the economic impact linked to quantity and quality of life losses, DALYs are calculated by multiplying the number of women with depression or anxiety, disability weights for depression and anxiety and the duration over which the problems are assumed to last. Whilst for depression we use disability weights distinguishing between moderate and severe depression, for anxiety we use a single disability weight for moderate anxiety; we assume for both depression and anxiety that the duration of the episode is 3 months (Garman et al., 2019). To estimate DALYs for the proportion of women with persistent depression or anxiety, the same approach is chosen, i.e., disability weights for moderate and severe depression are applied, whilst for anxiety the disability weight for moderate anxiety is applied for all women. DALYs are then converted to monetary values by applying 0.5 of GDP per capita, and present cost values are derived by aggregating discounted values over the whole period (year of pregnancy to 10 years after birth). Women's productivity losses are calculated using data on average hours of lost productivity due to absenteeism and presenteeism for people with mental health problems (Andrade et al., 2013; Baptista et al., 2019; Franca, 2014). Data referred to estimates representative for the general population in Brazil as no data are available for women with perinatal mental health problems specifically. Data on average hours are multiplied by average hourly income of women in Brazil. A present value is derived by aggregating discounted values over the whole period (year of pregnancy to 10 years after birth). Details on parameters, how they are derived, and their data sources can be found in Table 2.

2.4.2. Costing adverse impacts on children

Economic impacts for children arise because of losses in quantity and quality of life (measured in DALYs), productivity losses and publicly funded healthcare costs. To measure the economic impact linked to quantity and quality of life losses, we first calculate DALYs for the number of infants born with low birth weight (linked to antenatal depression), and the proportion with subsequent attention problems, as well as for the number of children with internalising and externalising problems (linked to persistent postnatal depression). DALYs for low birth weight are taken from the Global Burden of Disease Results tool (http://ghdx.healthdata.org/gbd-results-tool). Since the estimate generated by the tool refers to all infants born in Brazil in 2017, we divide it by the number of infants born with low birth weight in the same year. To derive DALYs linked to attention problems for subsequent years, disability weights for attention deficit hyperactivity disorder are assigned to the number of children (here: girls) estimated to develop those problems due to antenatal depression. For calculating DALYs linked to internalising problems, a combined estimate of disability weights for moderate anxiety and depression is used, whilst for externalising problems, a disability weight for conduct disorder is assigned. As done before to value mothers' health impacts, DALYs are then converted to monetary values by applying 0.5 of GDP per capita, and a present value is derived by aggregating discounted values over the whole period (from birth to when children are aged 40 years).

Productivity losses are estimated for children with internalising and externalising problems (linked to persistent perinatal depression for the youth and adulthood period (from when children are 16 to 40 years)). As done in the calculations for mothers, productivity losses are calculated using data on average hours of lost productivity due to absenteeism and presenteeism for people with mental health problems (Andrade et al., 2013; Baptista et al., 2019; Franca, 2014), and data on average working hours lost per year are multiplied with the average hourly income. A present value is derived by aggregating discounted values over the whole period (16 to 40 years).

Finally, the costs of publicly funded hospital care is measured, which occurs shortly after birth for children born pre-term (linked to antenatal depression) in the form of neonatal intensive care (Menezes et al., 2012), and in the first two years in the form of treatment for infections and injuries (linked to postnatal depression) (Jacques et al., 2021). The additional risks are derived from studies conducted in Brazil (Jacques et al., 2021; Menezes et al., 2012), and multiplied by relevant unit costs and number of children exposed to maternal depression during the perinatal period. All values are discounted and aggregated to derive present values.

2.5. Sensitivity analysis

In sensitivity analysis, we include additional economic impacts, which are linked to women's suicide during the perinatal period. This is done to account for depression as important risk factor for suicide (Bachmann, 2018). Whilst DALYs are estimated based on a suicide rate of 3.1 per 100,000 in the general population of women in Brazil (taken from World Bank data) and a weight for years of life lost for someone dying during mid-life (taken from Global Burden of Disease data). Identifying accurate suicide rates is notoriously difficult for this population in low- and middle-income countries (Fuhr et al., 2014) and this the figure is likely to underestimate true numbers substantially.

3. Results

Our findings are shown in Table 3. On left side of Table 3, the total costs of perinatal depression and anxiety, in the absence of scaled-up treatment, are presented in the form of the average cost per woman giving birth, as well as the total cost across the population of women who are pregnant in 2017. (We estimate this number to be 2,890,616 women, using the method described above.) Values reflect present (i.e., discounted) values of the costs as they occur over the lifetime for the hypothetical 2017 cohort of women and the children, they give birth to in that year. As described above, this refers to a time horizon of ten years for the women's cohort and of 40 years for the children's cohort. DALYs (which are converted into US dollars) only represent years lost due to disability and do not include years of life lost due to death linked to depression or anxiety, such as through suicide. The right side of Table 3 shows the results from sensitivity analysis, in which the costs of suicide during the perinatal period are added to the costs of perinatal anxiety and depression.

Our findings presented in Table 3 show the high-cost impacts of depression and anxiety during the perinatal period for both mothers and children. The total lifetime cost of these conditions is USD 4.86 billion or R$ 26.24 billion. The largest proportion of costs are those to society in the form of quality-of-life losses due to disability (USD 2.65 billion) and productivity losses (USD 2.16). Costs of healthcare are also substantial (USD 0.05 billion), linked to infant or child hospital care occurring in the first two years of life. Lifetime costs of perinatal depression and anxiety per child born are USD 1692, including impacts on both mother and child. If it is assumed that costs occur at the same rate over a 40-year period, then this would be equivalent to yearly costs of USD 0.66 billion for the total Brazilian population and USD 73 per child born, linked to just one annual cohort of mothers and children. (Similar costs would be generated for each previous and subsequent cohort.) When the costs of maternal suicide are included, the total costs increase to USD 4.93 billion due to additional loss in life years lost (USD 0.24 billion) and productivity loss (USD 0.48 billion).

Table 3
Costs of perinatal depression and anxiety per woman giving birth and per cohort of women giving birth (based on 2017 data, in USD), findings from base case and sensitivity analysis.

	Findings from base case: costs of perinatal depression and anxiety		Findings from sensitivity analysis: costs of perinatal depression, anxiety & suicide	
	Per woman giving birth	Per cohort in 000's	Per woman giving birth	Per cohort in 000's
Mother				
DALY loss	345	997,086	354	1,020,952
Income loss	744	2,134,948	761	2,182,680
Child				
DALY loss	576	1,652,281	576	1,652,281
Income loss	10	27,836	10	27,836
Hospital costs	17	47,676	17	47,676
Total cost (mother + child)	1692	4,859,826	1692	4,859,826

4. Discussion

Our findings suggest that the lifetime costs linked to perinatal anxiety and depression in Brazil are very high, thus adding to growing evidence about the substantial costs of mental health problems in low- and middle-income countries. Globally, the costs of anxiety and depression across the whole adult population have been estimated at USD 1.15 trillion per year (Chisholm et al., 2016). The cost of maternal depression because of the impact on just a single indicator, child stunting, has been estimated at USD 14.5 billion worldwide (Smith Fawzi et al., 2019). To our knowledge, ours is the first study to estimate the costs of maternal mental health problems in a Latin American country setting. Innovatively, it includes the economic consequences linked to negative effects of maternal depression on children. By including the long-term and intergenerational effects on costs, we sought to address limitations of past cost studies of mental health problems that have been highlighted by the World Health Organization (Chisholm et al., 2016). It is possible to include those impacts because of the high-quality longitudinal evidence available in Brazil, which includes a large birth cohort study, the Pelotas study, that followed up mothers and children over time and thus allowed examination of the long-term impacts of maternal depression and anxiety during the perinatal period and beyond on the child. Our analysis sets out an important part of an economic case for investment.

Government agencies like the World Health Organization have, over recent decades, called for strategies to improve maternal mental health, including as part of broader development goals on gender empowerment, early child development and poverty reduction (World Health Organization, 2008). However, despite robust evidence about the high prevalence of maternal depression and anxiety, as well as their detrimental impacts on women and children, maternal mental health is still a neglected area in terms of policy, services, and research (Rahman et al., 2013b).

Globally, a large amount of evidence suggests the effectiveness and cost-effectiveness of treatment approaches, such as those building on cognitive behaviour therapy, to prevent or reduce perinatal depression and anxiety (Bauer et al., 2016a; Howard et al., 2014; Rahman et al., 2013a). They are part of the intervention package recommended by the World Health Organization (WHO, 2016). Effective and (cost-)effective approaches for increasing access to treatment for maternal depression and anxiety in ways that are affordable in a low- or middle-income country context may include task shifting (Rahman et al., 2013b) as well as utilising digital technologies, both of which have been identified as feasible to implement in Brazil (Rocha et al., 2021). The importance of addressing maternal mental health problems early on to prevent adverse mental health and wellbeing impacts on children is particularly relevant in the context of scarce investments into mental health services provided to children and young people, which is disproportionally low when compared with investment in mental health services for the adult population (Paula et al., 2014; Paula et al., 2012). In addition to a relatively well functioning antenatal care system, which can be utilised for identifying women at risk of mental health problems (Jacques et al., 2021), innovative early child development programmes like the Programa Criança Feliz (Happy Child Programme) and Programa Infância Melhor (Better Early Childhood Programme) also exist and can incorporate mental health treatment and support. Indeed, some of them already include comprehensive assessments of the social, economic and (mental) health situation of women, thus offering opportunities to incorporate mental health treatment and support in line with international guidance (WHO, 2016).

Our study has several limitations. Several economic impacts could not be included in the analysis because of lack of data, therefore some of the results may be underestimated. Comparing findings from this paper with estimates from our previous work in the UK (Bauer et al., 2016b), cost per capita are substantially lower. For example, the cost per

100,000 births in Brazil is USD 0.17 billion (=£0.12 billion), which is a fraction of the cost we found in the UK (just under £1 billion per 100,000 births). This is partly explained by the lack of data on long-term costs for children with developmental or mental health problems, including those that occur for paying for school support, hospital treatment and criminal justice services. In addition, lower values attached to quality of life and productivity losses reflect lower wages in Brazil, in particular for women, as well as lower investments in publicly funded health and social care. (The gender wage gap in Brazil is particularly large.) Other limitations of this study included that we are unable to consider the costs linked to impacts on partners, families and the wider community because of maternal mental health problems, for example when those step in to provide unpaid care to mothers and their children. Additionally, we are unable to include the well-established effects of depression on mother's physical health. (Both of these limitations also affected our UK study.) Although the analysis uses data in which the relationships between perinatal depression and adverse child outcomes are analysed by controlling for other factors that are likely to influence the relationship, such as socio-economic status, previous depression or domestic violence, it is not possible to infer causality. Instead, some of the impacts on children might be caused by wider, complex circumstances, which need to be considered when designing interventions to reduce the human and economic consequences of maternal depression and anxiety. The importance of addressing major social determinants of mental health problems through intervention has been highlighted (Lund et al., 2018). The figures presented in this paper are not necessarily 'preventable costs' although, considering the strong cost-effectiveness evidence, it is likely that some of the burden can be prevented with the right interventions. Further economic analysis, such as return-on-investment analyses, is needed to establish exactly how much of the burden can be reduced with interventions. Our study emphasises the need for more research, including efforts to establish the prevalence and impact of severe mental health conditions during the perinatal period, which – whilst rare – often have devastating impacts on mothers, families and communities. Considering rapidly changing environments, amply demonstrated by the Covid-19 pandemic, cost studies may date quite quickly and should be repeated on a regular basis. However, this requires the availability of good quality, up-to-date data on, for example, prevalence of mental health problems.

In conclusion, this paper makes the economic case for investing in screening, treatment and support for women's mental health problems during the perinatal period to ensure that mental health care is provided with parity alongside physical health care as part of comprehensive maternal and early childcare programmes.

CRediT authorship contribution statement

Annette Bauer: Conceptualization, Investigation, Methodology, Project administration, Writing – original draft. **Martin Knapp:** Supervision, Resources, Writing – review & editing. **Alicia Matijasevich:** Investigation, Formal analysis, Writing – review & editing. **Ana Osório:** Investigation, Project administration, Writing – review & editing. **Cristiane Silvestre de Paula:** Investigation, Project administration, Writing – review & editing.

Conflict of interest

None.

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