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Changes in preterm birth and stillbirth during COVID-19 lockdowns in 26 countries

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Title

Changes in preterm birth and stillbirth during COVID-19 lockdowns in 26 countries

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Abstract

Preterm birth (PTB) is the leading cause of infant mortality worldwide. Changes in PTB rates, ranging from -90% to +30%, were reported in many countries following early COVID-19 pandemic response measures ("lockdowns"). It is unclear whether this variation reflects real differences in lockdown impacts, or perhaps differences in stillbirth rates and/or study designs. We present interrupted time series and meta-analyses using harmonized data from 52 million births in 26 countries, 18 of which had representative population-based data, with overall PTB rates ranging from 6% to 12% and stillbirth ranging from 2.5 to 10.5 per 1,000 births. Here we show small reductions in PTB in the first [odds ratio 0.96, 95% confidence interval 0.95-0.98, p-value<0.0001], second (0.96, 0.92-0.99, 0.03), and third months of lockdown (0.97, 0.94-1.00, 0.09), but not in the fourth month of lockdown (0.99, 0.96-1.01, 0.34), although there were some between-country differences after the first month. For high-income countries (HICs) in this study, we did not observe an association between lockdown and stillbirths in the second (1.00, 0.88-1.14, 0.98), third (0.99, 0.88-1.12, 0.89) or fourth (1.01, 0.87-1.18, 0.86) month of lockdown, although we have imprecise estimates due to stillbirths being a relatively rare event. We did, however, find evidence of increased risk of stillbirth in the first month of lockdown in HICs (1.14, 1.02-1.29, 0.02) and, in Brazil, we found evidence for an association between lockdown and stillbirth in the second (1.09, 1.03-1.15, 0.002), third (1.10, 1.03-1.17, 0.003) and fourth (1.12, 1.05-1.19, <0.001) month of lockdown. With an estimated 14.8 million PTB annually worldwide, these modest reductions translate into large numbers of PTB averted globally and warrant further research into causal pathways.

Main text

Main

Approximately 10% of babies are born preterm (i.e., before 37 completed weeks gestation), corresponding to nearly 15 million preterm births annually[1]. Preterm birth and related complications are the leading cause of infant mortality, and those who survive face an increased risk of morbidity and mortality across the life course[2]. While most preterm births are spontaneous, some are planned to reduce the risk of adverse outcomes including stillbirth, which account for two million *in utero* deaths globally each year[3,4]. A decline in preterm birth rates can therefore be an indicator that high-risk women and their babies are not receiving timely, quality care, potentially leading to increases in stillbirths.

In the first few months following the introduction of pandemic-related restrictions (henceforth referred to as "lockdowns") in response to the first wave of Coronavirus disease 2019 (COVID-19), there were markedly varying reports of changes in preterm birth and stillbirth rates across countries. Substantial reductions in preterm birth were reported from a number of high-income countries (HICs), including Australia (29-36%)[5,6], Israel (40%)[7], and some European countries (16-91%)[8–13]. Conversely, data from Nepal, Uruguay, and California showed increases of 11-30% in preterm birth rates[14–16], whereas national data from Canada, Spain, Sweden, and the USA indicated small or no changes[17–22]. In parallel, studies from low- and middle-income countries (LMICs; Nepal and Nigeria) and HICs (UK and Italy) reported

increases in stillbirth rates of 2-22%[12,14,23,24], but few studies analyzed preterm birth and stillbirth in parallel.

There have been several systematic reviews and meta-analyses examining the impact of pandemic restrictions on perinatal outcomes. These studies have generally found insufficient evidence to suggest an overall change in global preterm birth and stillbirth rates, but they have reported changes in certain subgroups[25–27]. For example, when restricting to studies from HIC settings, Chmielewska *et al.* found a decrease in preterm birth rates (crude odds ratio (OR) 0.91, 95% confidence interval (CI) 0.84-0.99; 795,105 pregnancies from 12 studies) and an increase in stillbirth rates (OR=1.28, 95% CI=1.07-1.54; 367,288 pregnancies from 12 studies)[27]. However, comparison across studies was hampered by methodological differences. Notably, only one study in the review accounted for pre-pandemic trends in preterm births in their analysis[10,28]. Additionally, most studies used facility-based data, which are difficult to interpret because changes in perinatal outcome rates at individual health facilities could reflect lockdown-induced changes in healthcare delivery (e.g., diversion of high-risk births from one facility to another) rather than true population-level changes in perinatal outcomes. Indeed, a living systematic review and meta-analysis demonstrated important differences in the estimated impact of pandemic restrictions on preterm birth, depending on whether the study used single centre (10% relative reduction: adjusted OR=0.90, 95% CI=0.86-0.94; 183,422 pregnancies from 20 studies) or regional/national-level data (no change: adjusted OR=0.99, 95% CI=0.94-1.03; 1,385,403 pregnancies from eight studies)[26].

While methodological challenges have hindered robust conclusions on whether lockdowns led to reductions in preterm births, there were undoubtedly unprecedented health, social and economic impacts that occurred as part of lockdowns that could potentially lead to reductions in preterm birth rates[29]. The most well-established cause of spontaneous preterm birth is infection[30], and it is plausible that an immediate and substantial reduction in circulating infections during lockdown, due to reductions in social interaction and increased hygiene measures[31,32], could directly influence preterm birth rates. Additionally, observational studies have shown an increased risk of poor pregnancy outcomes at times of high air pollution, particularly in association with exposure in the third trimester[33,34]; thus, reductions in air pollution linked with lockdown could potentially have an immediate impact on preterm birth [35,36]. It is, however, also plausible that any reduction in preterm birth rates might signal that high-risk women were not receiving timely and quality maternity care[37], and the reduction in preterm births may have been offset by an increase in stillbirths.

Given the uncertainties in the available evidence on the impact of COVID-19 pandemic lockdowns on perinatal outcomes, particularly where studies have not used population-based data, we aimed to conduct a rigorous, standardized analysis using high-quality data from across the world through the International Perinatal Outcomes in the Pandemic (iPOP) study. Specifically, we explored whether lockdowns in response to the first wave of the COVID-19 pandemic were associated with a change in preterm birth rates using interrupted time series (ITS) analysis, and whether any associations identified varied by country income level or by type or timing of preterm birth, or could be explained by changes in stillbirth rates. Detailed time-series data enabled us to use pre-lockdown trends in preterm birth and stillbirth rates to

forecast the expected trend in these outcomes had lockdown not occurred, and compare these forecasted rates to the observed rates for each country individually and combined across countries in a meta-analysis.

Results

Study population and preterm and stillbirth rates

We included 52,067,596 births occurring between January 2015 and July 2020. Of these, 51,340,025 (98.6%) were from the 18 population-based datasets capturing whole countries or regions and 727,571 (1.4%) were from the 26 non-population-based datasets (**Supplementary Table 1**). A total of 3,115,628 births were from the lockdown period (i.e., the first four months after the stringency score first exceeded 50 on the Oxford COVID-19 Government Response Tracker Lockdown Stringency Index (henceforth "Oxford Stringency Index[38]). As described in **Supplementary Table 2** and **Supplementary Figure 1**, non-population-based datasets from five countries were excluded from the analysis due to data availability and quality issues. Lockdowns remained above the threshold of 50 on the Oxford Stringency Index in most countries throughout the four month lockdown period used in this study, apart from Finland, Iceland, Norway, and Switzerland (**Supplementary Figure 2**).

As shown in **Table 1**, among population-based datasets, the preterm birth rates (<37 weeks gestation) across the study period ranged from 5.8% (Finland) to 11.8% (Brazil); very preterm birth rates (<32 weeks gestation) from 0.8% (Finland, Peru) to 2.0% (Brazil);

spontaneous preterm birth rates from 2.8% (New South Wales, Australia) to 9.2% (Brazil); and stillbirths from 2.5 per 1,000 births (Finland) to 10.4 per 1,000 births (Brazil). Temporal trends in preterm birth rates for each country are shown in **Figure 1**, with equivalent plots for very preterm, spontaneous preterm birth and stillbirth rates in the Extended Data (**Extended Data Figures 1-3**). In the non-population-based data, there was wide variation in preterm and stillbirth rates both within and between countries (**Table 2** and **Supplementary Figures 3-12**).

Data quality

Data quality was generally high in the population-based datasets, with most having <1% missing data on gestational age and <5% difference in observed versus expected total number of births during the lockdown period (**Table 1**). Among non-population-based datasets, there were low levels of missing data on gestational age (<1%) in datasets from Asia, Europe, North America, and Latin America; however, some datasets from sub-Saharan Africa had substantial (up to 21%) missing information on gestational age. In addition, the total number of observed births differed by >10% (either increase or decrease) from expected during the lockdown period in some non-population-based datasets (Hong Kong, Poland, and in some facilities in Ghana, Kenya and Nigeria) (**Table 2**). These quality issues among non-population-based datasets support our *a priori* decision to focus the primary analyses on population-based datasets.

Association between lockdown and preterm birth

Figure 2 shows the country-specific OR for the impact of lockdown on preterm birth, for each month of lockdown (additional detailed plots: **Supplementary Figures 13-16**). In the first month, for example, the OR for the impact of lockdown on preterm birth ranged from 0.87 in Iran (95% CI=0.78-0.98) to 1.24 in Iceland (95% CI=0.71-2.16). Our meta-analysis of population-based data indicated small reductions in preterm birth in the first (OR=0.96, 95% CI=0.95-0.98, p<0.001), second (OR=0.96, 95% CI=0.92-0.99, p=0.03), and third month (OR=0.97, 95% CI=0.94-1.00, p=0.09) of lockdown, but none in the fourth month (OR=0.99, 95% CI=0.96-1.01, p=0.34) (**Figure 3**). Between-country heterogeneity (I^2) was 0%, 64%, 53% and 34% for the first to fourth month of lockdown, respectively. Stratifying by country income level indicated similar reductions in the odds of preterm birth for both high and upper-middle-income country settings, with higher between-country heterogeneity among upper-middle-income countries (**Figure 3**).

There was a wider range of ORs across the non-population-based data with, for example in the first month of lockdown, ORs of 0.38 (95% CI=0.17-0.87) in one facility in Nigeria, and up to 1.91 (95% CI=0.97-3.76) in another facility in Nigeria (**Extended Data Figure 4** and **Supplementary Figure 17**). There was no evidence for an association between lockdown and preterm birth in the meta-analysis of the non-population-based data (**Figure 3, Extended Data Figure 4** and **Supplementary Figures 17-20**).

For very preterm births, there was no evidence of an impact of lockdown over the four months of lockdown (**Figure 4, Extended Data Figures 5-6** and **Supplementary Figures 21-28**),

with ORs for all population-based datasets varying between 1.00 and 1.02 and CIs spanning the null value. For spontaneous preterm births, in the subset of countries with data available, there were small relative decreases (3-4%) in the first three months following lockdown in HICs, but not in Brazil, the only upper-middle-income country providing these data (**Figure 5, Extended Data Figure 7** and **Supplementary Figures 29-32**). There was also evidence for a decrease in the fourth month of lockdown only using the non-population-based data (OR=0.88, 95% CI=0.78-0.99, p=0.04, I^2=0%) (**Figure 5, Extended Data Figure 8** and **Supplementary Figures 33-36**).

Association between lockdown and stillbirths

The OR for the impact of lockdown on stillbirth ranged from 0.80 in Finland (95% CI=0.34-1.91) to 1.35 in New South Wales, Australia (95% CI=0.93-1.96) in the population-based data in the first month of lockdown (**Extended Data Figure 9** and **Supplementary Figure 37**). In the meta-analysis of the population-based datasets, we found no clear evidence of an impact of lockdown on stillbirth in the first month of lockdown overall (OR=1.04, 95% CI=0.99-1.09, p=0.10, I^2=0%), but an increase was observed when restricting to HIC (OR=1.14, 95% CI=1.02-1.29, p=0.02, I^2=0%), driven by Canada (OR=1.26, 95% CI=1.04-1.51, p=0.02) (**Figure 6, Extended Data Figure 9 and Supplementary Figure 37**). There was an increase in the odds of stillbirth across all population-based datasets in the second (OR=1.07, 95% CI=1.02-1.12, p=0.001, I^2=0%), third (OR=1.08, 95% CI=1.02-1.13, p=0.004, I^2=0%) and possibly fourth month (OR=1.07, 95% CI=1.00-1.15, p=0.07, I^2=11%) of lockdown. These ORs were driven largely by Brazil (**Extended Data Figure 9** and **Supplementary Figures 38-40**), and when we restricted the meta-analysis to HIC only, we found no evidence for an association between lockdown and

stillbirth in the second month (OR=1.00, 95% CI=0.88-1.12, p=0.98, I^2=0%), third month (OR=0.99, 95% CI=0.88-1.12, p=0.89, I^2=0%) and fourth month (OR=1.01, 95% CI=0.87-1.18, p=0.86, I^2=13%) of lockdown (**Figure 6**).

In the non-population-based data, the ORs for stillbirth in the first month of lockdown ranged from 0.24 in a facility in Nigeria (95% CI=0.08-0.69) to 3.20 in a facility in Poland (95% CI=0.61-16.74) (**Extended Data Figure 10** and **Supplementary Figure 41**). We observed increased odds of stillbirth for the third and fourth months of lockdown in the meta-analysis of non-population-based data with relatively low levels of between-study heterogeneity at 0% and 18%, respectively (**Figure 6, Extended Data Figure 10** and **Supplementary Figures 41-44**); however, confidence intervals were wide and included the null value.

Sensitivity analyses

Sensitivity analysis of the population-based data restricting the analysis to only live births (**Supplementary Table 3**) and restricting to only births from 28 weeks gestation onwards (**Supplementary Table 4**) led to negligible changes in the country-specific estimates of the impact of lockdown on preterm birth rates. Similarly, excluding data from Brazil and the USA, which together contributed slightly over 70% of the births included in the study, from the meta-analysis of the ORs for the association between lockdown and preterm birth among population-based datasets led to negligible changes in our estimates (**Supplementary Table 5**).

Discussion

In this international study, we have reported on the impact of pandemic-related lockdowns on preterm birth and stillbirth. We included over 52 million births from 26 countries, largely derived from 18 population-based datasets from HICs and upper-middle-income countries. We observed small (3-4%) relative reductions in the overall rates of preterm birth following lockdown, although with some variation among countries. Reductions in spontaneous preterm birth rates were observed in HICs only, and no change in very preterm birth was observed. The observed decrease in preterm births did not appear to be driven by a reciprocal increase in stillbirth rates in HICs. We did, however, find evidence for increases in stillbirth in Brazil in the second, third and fourth months of lockdown. It remains plausible that some reduction in preterm birth rates was linked to increased stillbirth rates in HICs, but we had limited power to detect this due to the relatively small number of stillbirths. Our patient partners' interpretation of these results are provided in the Supplementary Discussion.

Multiple studies have assessed the effects of pandemic lockdowns on perinatal outcomes following initial reports of dramatic reductions in preterm birth rates[8,10,11], and several meta-analyses have been conducted[25–27]. However, there have been significant differences in data quality across prior studies, many of which did not apply analytical approaches that could account for pre-pandemic trends in perinatal outcomes[28]. Notably, few studies have included both preterm birth and stillbirth rates, despite the importance of considering perinatal outcomes together[39,40]. Our findings provide evidence by applying an ITS design to high-quality population-based data from 18 countries, and evaluating potentially

competing outcomes (i.e., preterm birth and stillbirth) in parallel. Even though we used the same analytical approach across data from different countries, between-country differences in the association between lockdown and both preterm birth and stillbirth rates were seen. These could be driven by contextual differences in the implementation of lockdown and differences in the impact of lockdown, which in turn, may be driven by the resilience of health or social systems.

Lockdowns had significant and diverse impacts on several exposures known to influence preterm birth, offering some possible explanations for the small reductions observed in our study. For spontaneous preterm birth, although the etiology is poorly understood, putative mediating factors include reductions in air pollution and, in particular, non-COVID infections both of which were shown to decline across a diverse range of countries, albeit to varying degrees[32,35,41]. It is possible that a reduction in physician-initiated preterm births also contributed to the overall reduction in preterm birth in some settings[6,42], although we could not investigate this directly, as data on medically indicated preterm births were not available for all countries and could not be reliably inferred. The increase in stillbirth with lockdown in some countries might reflect reduced access to timely quality antenatal and intrapartum care[43]. As our findings represent the average impact of lockdown across populations, we cannot differentiate the relative contribution of specific factors, nor whether the impact of lockdown differed between specific population subgroups. For example, an increased risk of preterm birth in some women (e.g., due to reduced access to care) might have been offset at the population level by public health responses reducing other risk factors, such as non-SARS-CoV-2 infections and air pollution.

Using aggregate data, it was not possible to distinguish the impacts of SARS-CoV-2 infection from those of pandemic-related restrictions. Relative to the essentially universal exposure of all pregnant women to lockdowns, only a small fraction[19] experienced SARS-CoV-2 infection at this early stage of the pandemic. As SARS-CoV-2 infection increases the risk of both preterm birth and stillbirth[44–46], it is possible that our results have underestimated the impact of lockdown on preterm birth and overestimated the impact on stillbirth, although any influence would be minimal given the relatively much smaller proportion of women experiencing infection compared to the broader effects of lockdown.

Our results highlight the paucity of population-based data in many settings, and the challenges of interpreting non-population-based data to assess changes in perinatal outcomes over time. First, in some countries, we observed large variation in preterm birth and stillbirth rates between facilities. These might reflect differences in case-mix as well as challenges in accurate reporting of key variables, particularly in estimating gestational age when routine antenatal ultrasound is unavailable. Second, some facilities within the same country documented markedly different impacts of lockdown on preterm birth and stillbirth rates. In some countries, there were dramatic shifts in how and where pregnant women accessed intrapartum care[14,] urging caution in the interpretation of results from studies of single facilities. In addition, the paucity of population-based data in LMICs - where the majority of preterm births and stillbirths occur[30,47,48] - was striking. We made extensive efforts to identify high-quality data from across different country income levels, including iterative development of the data collection tools with groups from a range of different countries and, in consideration of the more intensive data preparation required in some countries to harness

data on perinatal outcomes, special funding allocations to support the preparation of data from LMIC settings. While there have been significant efforts globally to improve perinatal data and outcomes through stillbirth and preterm birth prevention initiatives, such as Every Newborn Action Plan[49] and parent-led global organisations such as the International Stillbirth Alliance[50], we echo previous calls for the urgent need to develop systems that routinely capture high-quality data on perinatal outcomes with standardized definitions across countries[51, 52].

The strengths of our study include the broad global coverage, use of pre-defined and internationally recognised outcome measures, and analytical approaches to account for time trends and seasonal patterns in perinatal outcomes[53], as well as differentiation between population and non-population-based data and country income settings.

We acknowledge several limitations. First, we defined onset of lockdown as the month during which a country first exceeded 50 on the Oxford Stringency Index[38]. This is a crude measure to approximate the severity of pandemic-related restrictions in each country as a whole; it does not reflect within-country variations or individual experiences in lockdown measures. The Oxford Stringency Index also does not capture variations in access to maternity and healthcare nor provide information on the extent to which restrictions were enforced or followed. This is likely to be particularly problematic for large countries such as Brazil and the USA but, unfortunately, sub-national data on perinatal outcomes were not available for this study. Second, ITS analyses are vulnerable to confounding by unmeasured events occurring simultaneously to the intervention that might also impact the outcomes. Third, we used aggregate data and could not differentiate within-population differences on the impact of

lockdown measures, which is likely to vary by socioeconomic status, region, and age. Fourth, as we focused on the association between lockdown and perinatal outcomes for the first four months following the lockdowns in response to the first wave of COVID-19, we mainly captured the potential impact of lockdown on pregnancies that were in their third trimester at the start of lockdown; further studies should be conducted to assess whether there was an association between lockdown and perinatal outcomes for pregnancies that were at earlier gestations in lockdown. Fifth, where we found no evidence for an association (e.g. for stillbirth, very preterm birth and spontaneous preterm birth in all or some settings), we cannot rule out that there was no change as these were relatively rare with wide confidence intervals. The use of equivalence tests to formally test whether there was no evidence for a clinically meaningful change in our outcomes were considered but ultimately not conducted as there is no minimum clinically meaningful difference for stillbirth or preterm births, with any change of interest. Finally, the interpretation of our results is limited by difficulties with data capture, population coverage and data quality from some countries. We therefore conducted separate analyses for population-based data considered to be of high quality, yielding more robust estimates.

In summary, this international study provides evidence on global changes in preterm birth and stillbirth across 26 countries during the initial COVID-19 pandemic lockdowns. Overall, we observed a 3-4% relative reduction in the preterm birth rate during the first three months of lockdown based on population-based data from HICs and upper-middle-income countries. This decrease in preterm births did not appear to be linked with an increase in stillbirths in most settings. Consistent evidence of an increase in stillbirths was only observed in Brazil following lockdown, the causes of which certainly warrant further exploration. Although

relatively small, these changes in preterm birth are meaningful at the population level: assuming the observed decline during lockdown is real and consistent worldwide, our findings suggest that nearly 50,000 preterm births (or approximately four per 1,000 live births) were averted in the first month of lockdown alone, based on a global pre-pandemic preterm birth rate of 10.6%[1]. Understanding the underlying pathways linking lockdown with the reduction in preterm births could have implications for clinical practice and policy. Our study highlights the need to develop further capacity for high quality and appropriate standardized data collection in LMICs[54]. Finally, the iPOP platform offers novel opportunities to rapidly conduct harmonized perinatal health research globally during the COVID-19 pandemic and beyond.

Methods

We engaged with national and subnational data custodians to standardise and analyse aggregate-level data on monthly numbers of births stratified by gestational age from population-based data sources, and to conduct exploratory analyses using non-population-based data sources. Detailed time-series data enabled us to use pre-lockdown trends in preterm birth and stillbirth rates to forecast the expected trend in these outcomes had lockdown not occurred, and compare these forecasted rates to the observed rates for each country individually and combined across countries in a meta-analysis. The study was conducted using a common protocol[56] and reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guideline[57].

Ethical considerations

Contributors from countries where the data were not publicly available obtained ethics approval from their respective institutional review boards (**Supplementary Table 6**). We did not seek ethical approval for publicly available data sources (**Supplementary Table 6**). All data contributors completed a Data Contribution Agreement, which outlined the terms and conditions for uploading and storing data to the SAIL Databank[58].

Study data and population

We collected aggregate data from 26 countries (**Supplementary Table 1**). We considered data sources as population-based if they captured greater than 90% of births in the region or country, and non-population-based if coverage was ≤90%. There were 18 national and regional population-based data sources which, where possible, included all recorded births from 22+0 weeks gestation between January 2015 and July 2020. Births recorded as ≥45+0 weeks gestation were censored as unfeasible gestation of birth. Data were also included in the analyses if they were available for a shorter pre-pandemic period (Denmark, Iran and Peru), for live births only (Chile, Peru and USA), or used a slightly different cut-off for the lower limit of gestational age (≥24+0 weeks gestation in New South Wales, Australia and Wales, UK).

Data available from low- and lower-middle-income country settings were exclusively non-population-based, and we therefore included non-population-based data as part of the main analysis in a deviation from the original protocol[56], to provide insights across a range of countries by income levels. There were 26 non-population-based data sources from 10

countries, which included data from individual health facilities (23 datasets from seven countries), pooled data from a group of health facilities (two datasets from two countries), and demographic surveillance sites (one dataset from one country) (**Supplementary Table 1**). For Australia and the USA, there were both population-based and non-population-based data sources included in the analysis; the data sources from Australia covered different regions of the country whereas data sources for the USA covered some overlapping regions but were not included together in any analysis (as described below).

To ensure data and measures from different settings were comparable, consistent, and coherent, we developed a detailed protocol, including standardized outcome definitions and data collection templates[56], and stored and analyzed the standardised data in the Secure Anonymized Information Linkage (SAIL) Databank. We collected information on national income levels from the World Bank[59] (**Supplementary Table 1**). In our study protocol[56], we proposed to additionally collect national-level data on air pollution, adherence to lockdown, COVID-19 rates, world region and parental leave policy; we did not ultimately include these data due to: [1] not being able to identify readily available reliable data for all our study settings (air pollution and adherence to lockdown) or [2] finding little or no variation between the included datasets beyond that captured by country-income level (COVID-19 rates, world region and parental leave policy).

Defining lockdown

For each country, we defined the start of lockdown using the Oxford Stringency Index[38]. In brief, this index collects information on different social, health and economic government

policies instituted in response to the COVID-19 pandemic.

We considered the onset of a country's initial lockdown as the date at which the stringency score first exceeded 50 on the Oxford Stringency Index (range 0 - 100). This cut-off was pre-specified in the study protocol and based on expert advice. For dates of lockdown that occurred between the 1st and 15th of the month, the first month of lockdown was assigned to that month; for dates after the 15th, the first month of lockdown was assigned to the following month. As described below, we explored the impact on perinatal outcomes in the first four months from a country's initial lockdown, regardless of whether the Oxford Stringency Index dropped below 50 during this time. We restricted the analysis to the first four months to facilitate comparison between different countries included in this study; this was when the strictest lockdowns were in place in response to the first wave of COVID-19, with increasing variability between countries beyond this timeframe.

Defining perinatal outcomes

Data contributors recorded monthly numbers of births categorized into pre-specified gestational age groups, according to our data collection template. The outcome definitions aligned with global standard definitions for preterm birth and stillbirth[60,61] and were developed in consultation with our international collaborators to ensure that all data contributors captured these outcomes consistently.

For each month, we calculated the preterm birth rate per 100 births, as the number of births from 22+0 to 36+6 weeks gestation divided by the total number of births[62]. We

calculated the very preterm birth rate per 100 births as the number of births from 22+0 to 31+6 weeks gestation divided by the total number of births. We estimated the spontaneous preterm birth rate per 100 births as the number of births from 22+0 to 36+6 weeks gestation with spontaneous onset divided by the total number of births. The preterm, very preterm and spontaneous preterm birth rates were calculated, where available, using all births and live births only for settings where data on stillbirths were not available. We were not prescriptive in how data contributors should identify and define spontaneous births, beyond specifying that these should capture births preceded by spontaneous contractions or preterm prelabour rupture of membranes. Further details of the methods used to estimate gestational age across the different datasets are provided in **Supplementary Table 1**. The stillbirth rate was expressed per 1,000 births and calculated by dividing the number of stillbirths occurring from ≥22+0 weeks gestation by the total number of births.

Data analysis

A detailed description of the steps to clean and prepare the data before undertaking the analysis is provided in Supplementary Methods. In brief, we evaluated data quality and completeness of each dataset by: (1) assessing data completeness, including calculating the percentage of births missing gestational age; (2) examining for outliers in perinatal outcome rates; and (3) assessing whether there was any evidence for a change in the documented number of births after lockdown which, given the early stage of the pandemic when fertility will not have been affected, would suggest that women were giving birth in different locations or there were changes in recording practices (further details on analytical procedures in

Supplementary Methods). Any population-based datasets where there was a relative change of a 10% or more increase or decrease in the number of observed compared to expected total births following lockdown were excluded from the population-based analysis, and analyzed as a non-population-based dataset.

For each country-specific population-based dataset, we undertook an ITS analysis[63] to model the effect of lockdown on perinatal outcomes. First, we fitted weighted ITS models on the entire time series of the monthly log(odds) of the outcomes. Weights were based on the total number of births per month; imputed values for missing data (Supplementary Methods) were down-weighted to one (minimum possible number of births) to reduce bias from missing observations. Models accounted for seasonality (with inclusion of month as a fixed-effect) and long-term temporal trends, and we allowed the within-period trend and intercept to be different for the pre-lockdown and lockdown periods. Given that countries could have different trends in perinatal outcomes, we fitted five different potential models for each outcome for each country evaluating the trend as a linear, square, quadratic, logarithmic and second-order polynomial effect. The model with the lowest Akaike Information Criterion (AIC) was chosen as the best fit model[64]. We assessed the goodness-of-fit of the best model by examining the standardized residuals. Second, to compare the forecast of the best fit model to the post-lockdown observed values, we refitted the model to the pre-lockdown observations using the same trend effect selected through the AIC. This 'pre-lockdown model' was then used to forecast the expected rates of the perinatal outcomes for each of the first four months of lockdown assuming lockdown had not occurred. Plots of the observed and forecasted rates were used to visualize trends in outcomes over time. We calculated the OR between the

observed odds and the forecast odds of each perinatal outcome for each of the first four months of lockdown, a time period chosen to capture when lockdowns in response to the first wave of COVID-19 were implemented. We specified *a priori* to analyse each of the first four months of lockdown separately, as we hypothesized that the association between lockdown and perinatal outcomes would vary by month of lockdown given how rapidly public health measures evolved during this time. To analyse the non-population-based data, we used a linear regression model (rather than an ITS model) to forecast the log(odds) of perinatal outcomes in the first to fourth month of lockdown assuming lockdown had not occurred. This was due to non-population based datasets varying in data availability with respect to the pre-lockdown study period, frequency of reporting of outcomes, and degree of missingness. To capture changes by season and annual trends pre-lockdown in our forecasted estimates, the model included month (categorical) and year (continuous), with year also included as a squared term to account for settings with non-linear changes in the perinatal outcome rates over time. We then calculated the OR quantifying the impact of lockdown on the perinatal outcomes by dividing the observed odds of each perinatal outcome by the forecasted odds for each of the first four months of lockdown.

The ORs from each dataset for each perinatal outcome at each month after lockdown were pooled using random-effects meta-analysis[65], and this was done separately for the population-based data and the non-population-based data. For the population-based data, we stratified the meta-analysis by country income level (where sufficient datasets for each category permitted): high-income versus upper-middle-income. For non-population-based data, we used a three-level meta-analysis model to account for the dependency of

observations of the impact of lockdown between facilities in the same country[66]. The I^2 statistic, which captures the percentage of the variability in the ORs between countries that is due to heterogeneity rather than sampling error, was used to assess for evidence of between-country heterogeneity in the ORs[67]. We did not conduct equivalence tests to assess whether there was evidence that there was no association between the pandemic and our outcomes, as these tests require identifying a minimum clinically significant difference below which we would conclude that no change in our outcomes. There is no clear clinically significant difference that can be used for preterm birth or stillbirth, with any increase being of concern. Where relevant, we report p-values for the probability of observing a relative difference in our outcomes at least as big as that in our data under the assumption that there was no association between the pandemic and our outcomes.

All analyses were performed in R version 4.1.1.

Sensitivity analyses

We conducted three sensitivity analyses. First, to assess the potential impact of including datasets that only provided data on preterm birth among live births (rather than all births, 3/18 datasets) in the main analysis, we conducted ITS analysis restricted to live births among datasets which also provided data on all births (n=15 datasets). Second, to evaluate the impact of including datasets with a different lower limit for gestational age in the main population-based analysis for preterm birth, we restricted the time-series analysis to births from 28 weeks gestational age onwards, the lower threshold recommended by the World Health Organization for international comparisons[61]. Third, we also conducted a sensitivity

analysis for our meta-analysis of the association between lockdown and preterm birth among all population-based datasets, excluding Brazil and the USA which together contributed slightly over 70% of the births included in the study.

Public and patient involvement

Parent representatives from four national patient partner organisations were included from the inception of the iPOP study to inform the common goal of timely implementation of quality research. We used mechanisms to ensure meaningful collaboration through inclusion on meeting agendas and facilitating meeting processes so that everyone had an equal voice to ensure patient partners were treated with mutual respect. Patient partners from Brazil, Canada, Hungary, and Ireland co-developed the iPOP protocol, attended all iPOP meetings to ensure meaningful collaboration, edited and provided input to this manuscript, and are continuing to co-build meaningful and innovative knowledge translation strategies.

Data availability

This study makes use of anonymised data held in the Secure Anonymised Information Linkage (SAIL) Databank. We would like to acknowledge all the data providers who made anonymized data available for research (listed in **Supplementary Table 1**). The responsibility for the interpretation of the information SAIL supplied is the authors' alone. Data may be available to researchers for analysis after securing relevant permissions from the data contributors and the databank in which the data are held (SAIL Databank). The approvals process is managed by application to the SAIL Databank who hold data sharing agreements with the data providers.

Restricted datasets may require additional approvals from data custodians and ethical authorities in the relevant country/setting. Enquiries for data access should be made using the contact form at https://saildatabank.com/contact, or by making an enquiry to ICODA at https://icoda-research.org/contact/.

Code availability

Custom code that supports the findings of this study is available from the corresponding author Sarah Stock (sarah.stock@ed.ac.uk) upon request.

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Author Contributions Statement

C.C. prepared, analyzed and interpreted data, and led writing of the manuscript.

J.E.M. contributed to planning and conducting the study, analyzed and interpreted data, and contributed to drafting the manuscript.

M.B.A., M.B., D.B., N.R., S.J.S., H.Z. iPOP study co-leads, contributed to planning and conducting the study, interpreted data and contributed to drafting the manuscript.

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N.A., B.A., M.C-Y., D-T.C., K.C., N.F., M.F., A.H., L.Hui, K.H., A.KC., R.H.M., S.D.N., K.R.P., R.K.P., E.M.S., M.T., M.L.U., P.vD., C.W., K.Y-A. contributed to planning and conducting studies and revising the manuscript.

I.I.A., B.B., K.B., G.E-G., J.H., L.H., S.H., N.K., J.K., K.LD., N.M., V.N., C.O., D.P., M.P., V.S., K.W-S. acquired and/or interpreted and/or analyzed data.

A.B., L.R.B., I.F., A.F., T.O.O., S.S., G.A.W. contributed to drafting the manuscript.

Z.A.B., A.D.M., A.S. contributed to planning and conducting studies, critical appraisal and contribution to this work as well as contributed to securing funds.

All other authors reviewed and provided input to the manuscript.

Competing Interests Statement

M.B.A. holds a Tier 2 Canada Research Chair in the Developmental Origins of Chronic Disease at the University of Manitoba and is a Fellow in the Canadian Institutes for Advanced Research (CIFAR) Humans and the Microbiome Program. Her effort on this project was partly supported by HDR UK and ICODA.

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The remaining authors declare no competing interests.

Tables

Table 1: Data availability, overall preterm; very preterm; spontaneous preterm & stillbirth rates for population-based datasets, and data quality from 2015-2020 (exact time frames vary by country as outlined in Supplementary Table 1)

	Total number of births included	Monthly number of births, average	Preterm births %	Very preterm births %	Spontaneous preterm births %	Stillbirths per 1000 births	Data quality	
							Observed versus expected total number of births during lockdown**** %	% of births missing gestational age
Population-based data								
Asia-Pacific								
Australia, New South Wales*	518,281	7,853	6.4	0.9	2.8	3.4	-1%	0.1
Middle East & North Africa								
Iran	4,852,267	112,843	8.7	1.6	No data	7.9	+2%	0
Europe								
Belgium	665,086	10,077	8.6	1.5	6.0	6.1	No difference	0.02
Denmark, Central Region	66,481	1,231	6.0	1.0	No data	Not included*****	No difference	1.3
Finland	278,376	4,155	5.8	0.8	3.6	2.5	No difference	0.2
Hungary	501,860	7,604	8.8	1.5	No data	4.4	+3%	0.02
Iceland	23,463	350	6.4	0.9	2.9	2.7	-5%	0.5
Norway	316,067	4,789	6.4	1.0	3.6	3.3	-1%	0.2
Scotland**	288,118	4,300	8.6	1.3	4.4	4.1	-1%	0.3
Sweden	586,914	8,892	6.2	1.0	5.0	3.6	+3%	0
Switzerland	486,357	7,259	7.2	1.2	No data	4.1	+1%	0.03
Wales*	176,964	2,641	8.1	1.4	3.4	4.4	-5%	0.4
North America								
Canada	1,610,511	24,037	8.3	1.1	5.0	6.4	-2%	0.6
USA***	20,979,669	313,129	9.9	1.5	4.6	No data	-1%	0.1
Latin America & Caribbean								
Brazil	16,356,490	244,127	11.8	2.0	9.2	10.4	-8%	2.4
Chile***	1,244,121	18,567	8.5	1.3	8.4	No data	-5%	0.3
Peru***	2,156,486	39,935	6.6	0.8	No data	No data	-7%	0.001
Uruguay	232,514	3,523	9.5	1.5	No data	No data	+8%	1.3

*Only include births from 24 weeks onwards.

**Only includes births from 28 weeks onwards in the calculation for spontaneous preterm birth rates (as it is not possible to classify fetal losses at 22 and 23 weeks gestation as spontaneous or indicated)

***Only include live births.

****Ascertained by comparing the observed total number of births in the lockdown period to the forecasted total number of births calculated using a Poisson time series, which accounted for preceding seasonal and yearly trends.

*****Not included due to high levels of suppressed data.

Table 2: Data availability, overall preterm; very preterm; spontaneous preterm & stillbirth rates for non-population-based datasets, and data quality from 2015-2020 (exact time frames vary by country as outlined in Supplementary Table 1)

	Total number of births included	Monthly number of births, average	Preterm births %	Very preterm births %	Spontaneous preterm births %	Stillbirths per 1000 births	Data quality	
							Observed versus expected total number of births during lockdown** %	% of births missing gestational age
Hong Kong								
All public facilities (pooled)	199,134	3,064	8.4	1.4	No data	4.2	-13%	0
Australia, Queensland								
Facility 1	58,204	869	10.6	2.5	4.6	5.7	-2%	0
Matlab, Bangladesh								
Demographic Surveillance area*	29,705	443	13.5	1.6	13.5	15.6	+7%	0.3
Poland								
Facility 1	8,287	126	7.0	0.3	4.9	4.1	-20%	0
Facility 2	42,243	640	15.6	4.4	13.5	8.8	-13%	0.2
Washington state, USA								
14 facilities (pooled)	90,586	2,107	10.0	1.7	6.3	4.2	+10%	0
Mexico City, Mexico								
Facility 1	10,084	235	28.9	6.0	10.8	51.0	+10%	0.8
Ghana								
Facility 2	12,452	290	21.3	9.5	11.9	17.5	+8%	17.7
Facility 3	7,724	188	24.5	14.2	9.6	20.5	+8%	6.2
Facility 4	8,450	197	25.3	13.9	11.5	18.1	+4%	9.3
Facility 5	13,208	194	24.2	14.4	9.1	20.6	+6%	6.1
Facility 6	13,325	333	24.1	8.5	13.6	17.7	-18%	21.3
Facility 7	15,818	406	19.1	6.2	10.6	20.0	+17%	13.9
Facility 9	15,473	360	19.8	7.7	11.0	17.5	+1%	17.1
Kenya								
Facility 1	34,773	527	4.0	1.4	No data	20.4	+5%	1.7
Facility 3	51,790	909	3.3	0.7	No data	13.3	-32%	0.6
Nigeria								
Facility 1	7,275	110	22.2	7.4	6.7	49.2	-6%	0.2
Facility 2	6,923	107	15.4	3.2	14.2	41.5	+1%	1.7
Facility 3	12,118	181	8.4	0.2	6.8	42.4	-11%	17.1
Facility 4	5,267	79	16.2	5.6	15.5	45.0	+6%	3.4
Facility 8	8,808	131	7.2	1.5	No data	55.1	-1%	8.0
Facility 9	7,252	110	16.0	4.2	No data	59.0	-10%	9.3
Facility 10	17,457	265	16.1	3.4	6.8	106.9	+22%	3.1
Facility 11	10,361	155	21.6	7.4	No data	77.1	-55%	6.3
Facility 12	14,479	216	9.4	2.4	5.7	54.2	+1%	2.5
Uganda								
Facility 2	26,375	394	9.5	3.3	3.0	16.2	+2%	1.6

*Only includes births from 28 weeks onwards for stillbirths; **Ascertained by comparing the observed total number of births in the lockdown period to the forecasted total number of births calculated using a Poisson time series, which accounted for preceding seasonal and yearly trends.

Figure Legends

*Figure 1: Observed rates of **preterm birth** (amongst all births 22 weeks onwards) over time (2015-2020) for countries providing population-based data, with the forecasted preterm birth rates and 95% confidence intervals also plotted for the lockdown period. Lockdown period shown in shaded grey. Unless specified otherwise, preterm birth rates are the percentage of all births from 22 weeks onwards that were born before 37 weeks gestation. Left panel: entire study period (2015-2020) illustrating seasonality and trends over time. Right panel: 2020 period enlarged to show the observed and forecasted births during lockdown. Forecasted ("modelled") rates were estimated from a 'pre-lockdown model' which was used to forecast the expected rates of the preterm birth for each of the first four months of lockdown assuming lockdown had not occurred. *Preterm birth rates restricted to births from 24 weeks onwards; **Preterm birth rates restricted to live births only*

*Figure 2: Individual and pooled **population-based estimates** of the association between lockdown and the odds of **preterm birth** among all births 22 weeks onwards, stratified by time since lockdown. Individual country odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of preterm birth to the forecasted odds of preterm birth from an interrupted time series model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Pooled odds ratios (represented by diamonds on plot) for the association between lockdown and the odds of preterm birth were calculated using random-effects meta-analysis. Sample sizes for each country provided in Table 1.*
**Births from 24 weeks onwards **Live births only*

*Figure 3: Pooled odds ratios capturing the association between lockdown and the odds of **preterm birth**, stratified by month of lockdown, type of data (population-based, non-population based) and income setting. Pooled odd ratios (represented by boxes on plot) were calculated using random-effects meta-analysis. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals for the odds ratio. Arrows indicate upper and/or lower bounds of the confidence interval that are outside the x-axis limits.*

*Figure 4: Pooled odds ratios capturing the association between lockdown and the odds of **very preterm birth** (births at <32 weeks gestation), stratified by month of lockdown, type of data (population-based, non-population-based) and income setting. Pooled odd ratios (represented by boxes on plot) were calculated using random-effects meta-analysis. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals for the odds ratio. Lines surrounding each box on the forest plot are 95% confidence intervals.*

*Figure 5: Pooled odds ratios capturing the association between lockdown and the odds of **spontaneous preterm birth**, stratified by month of lockdown, type of data (population-based, non-population based) and income setting. Pooled odd ratios (represented by boxes on plot) were calculated using random-effects meta-analysis. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals for the odds ratio. Arrows indicate upper and/or lower bounds of the confidence interval that are outside the x-axis limits.*

*Figure 6: Pooled odds ratios capturing the association between lockdown and the odds of **stillbirth**, stratified by month of lockdown, type of data (population-based, non-population based) and income setting. Pooled odd ratios (represented by boxes on plot) were calculated using random-effects meta-analysis. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals for the odds ratio. Arrows indicate upper and/or lower bounds of the confidence interval that are outside the x-axis limits.*

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Table of Contents

Supplementary Methods

Data preparation and management

Suppressed data: For the few datasets where suppressed values were present due to small numbers (<5), these were inputted using two different methods depending on how data providers suppressed the data: (1) for datasets where the total number of births did not equal the total number of non-suppressed cells, we divided the number of non-allocated births by the number of suppressed cells and (2) for datasets where the total number of births equalled the total number of non-suppressed cells, we inputted the suppressed cell as the midpoint between 1 and the threshold for suppression (usually <5 births) and recalculated the total number of births.

Missing and outlier data: The distribution of the number of births with missing information on gestational age was investigated to determine if these data were missing at random with respect to lockdown. If there was no evidence to suggest that data missing was not at random and if the percentage of births missing information on gestational age did not change between the lockdown and pre-lockdown periods, then we assumed that these were missing gestational age completely at random and re-allocated these births proportionally across the gestational age groups. Where data on births were completely missing for a given month, linear interpolation of the outcome rates was performed using data from the six nearest surrounding time-points for the population-based data. For the non-population-based data, where there were higher levels of missing data for consecutive months in some of the datasets, we did not

input these values and only modelled using the observed data. We graphed the preterm and stillbirth rates for each month for each dataset to check that the fell within plausible ranges; all plots were reviewed by the statistical analysis team (including clinicians, statisticians and epidemiologists) and where implausible rates were identified, we followed-up with the data provider to check if there had been a data entry error. Where the rates could not be corrected, the implausible data points were treated as missing for analysis.

Bias in capture of births in lockdown: Given the early stage of the pandemic, we would not expect to see any changes in the number of births being observed in our data sources compared to pre-lockdown unless driven by a bias in which women were giving birth in different locations and not being recorded, or due to changes in recording practices. To assess this, we forecasted the expected total numbers of births using a Poisson time series, based on pre-lockdown seasonal and yearly trends, and compared the observed number of births to expected number of births. We calculated the percentage change in the total number of births in the lockdown period by dividing the observed total number of births by the expected number of births. Any population-based datasets where there was a relative change of 10% or more in the number of observed compared to expected births following lockdown were excluded from the population-based analysis, and analyzed as a non-population-based dataset.

Data Management: Data were stored and analyzed in the UK Secure Anonymized Information Linkage (SAIL) Databank[1,2], Swansea Wales, in compliance with the European General Data Protection Regulation guidelines, adhering to the global gold standard of data governance. All data contributors completed a Data Contribution Agreement (DCA) between their institution

and SAIL and were provided with a secure link to upload data directly to the SAIL repository.

To ensure outputs were confidential and safe, all statistical outputs were checked using Statistical Disclosure Control (SDC) procedures before being exported out of the virtual environment. We used SDC guiding principles from the Handbook on SDC for Outputs by the UK Data Service[3]. This prevented the identity of a birth from being revealed or inferred from outputs.

Supplementary Discussion

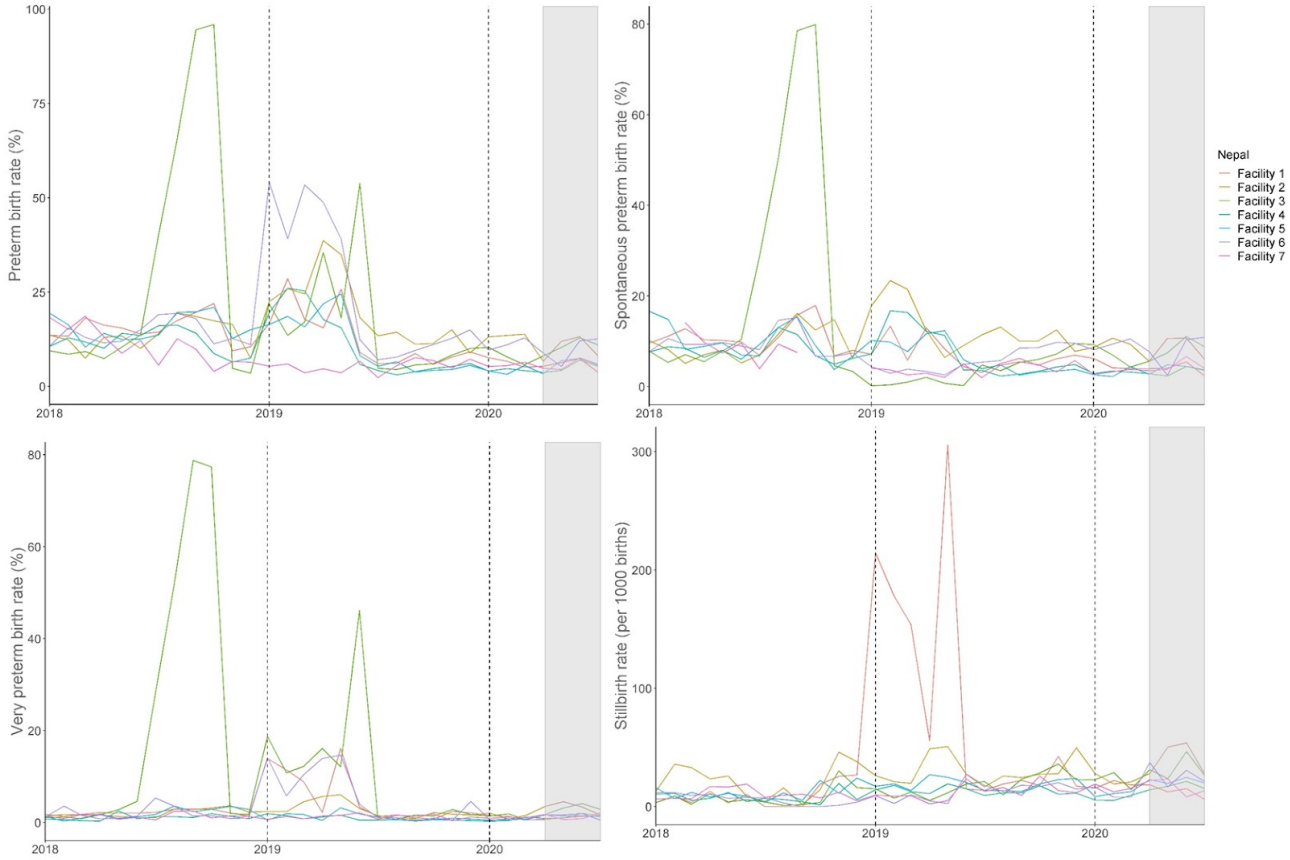
Patient Partner Interpretation

Behind every statistic, there is a story of a baby and a family. Patient organizations from around the globe were raising awareness about inequalities in the area of maternal and newborn health long before the COVID-19 pandemic. Disparities have existed between countries in the delivery of prenatal care for many years; however, the lack of robust data collection strategies and standardized birth registries have hampered efforts to understand these disparities and gain insight towards the underlying causes of preterm birth. As a patient community, we were optimistic that the iPOP Study findings might help us identify reasons why rates of prematurity and stillbirths may have declined in some countries early in the pandemic and that these 'reasons' might be leveraged to help reduce the global preterm birth and stillbirth rates. We perceive two major learnings from the iPOP Study: one related to the study results and another related to the challenges faced by the researchers.

The iPOP Study results revealed small differences in preterm and stillbirth rates during the COVID-19 pandemic, and while the scope of this paper did not identify a reason, we feel it may be due to the impact on access to care. The experience of patient organizations working with families who experience preterm birth indicate that because of pandemic enforced changes to maternal and neonatal care, the patient experience has been dramatically altered[55]. With access to existing care pathways and evidence-based family-centered care severely disrupted, patient organizations have reported increasing numbers of families seeking alternative sources of support and resources[4]. Our experience leads us to believe that the iPOP Study results are likely related to the significant shift in maternal and newborn care pathways around the globe.

The iPOP Study researchers faced many challenges related to data collection and quality. They had access to limited numbers of globally distributed data sets and obtaining comparable data, especially from LMICs, proved very difficult. These challenges lead us to conclude that maternal and newborn health is still not prioritized as a topic warranting immediate and urgent attention in numerous health systems around the world. GLANCE, the Global Alliance for Newborn Care was launched in 2019 by the European Foundation for the Care of Newborn Infants (EFCNI). Patient organizations from 15 countries contributed towards a Call to Action, advocating for the development of initiatives aimed at improving newborn and maternal health worldwide. Up-to-date, reliable data gathered through standardized methodologies is the cornerstone upon which future research and quality care initiatives must be built and as a collective voice. As such, we are calling for researchers and health providers to learn from the iPOP Study and the pandemic as a whole, to address the deficit in reliable and consistent global maternal and newborn health data.

Supplementary Figures



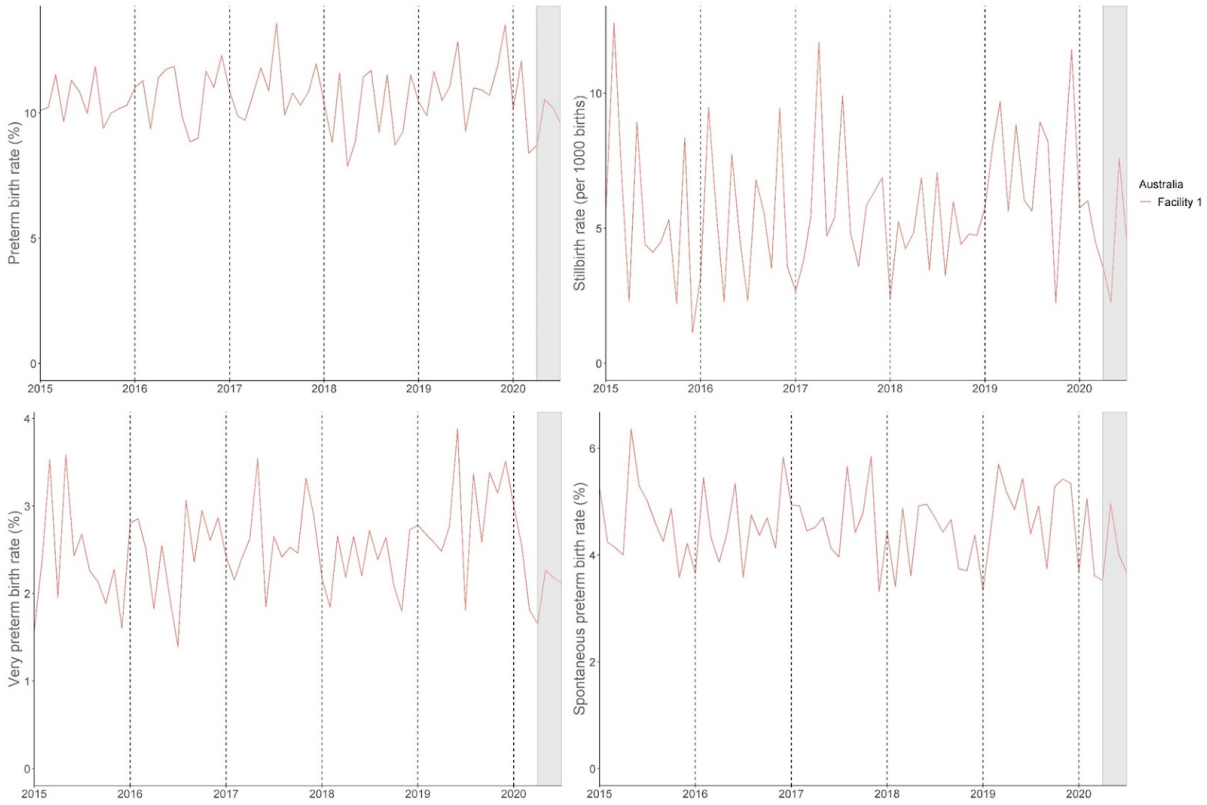
Supplementary Figure 1: Preterm birth rates, stillbirth rates, very preterm birth rates and spontaneous preterm birth rates among all births 22 weeks onwards over time in non-population-based datasets from ***Nepal (excluded)****, stratified by facility.*

Lockdown period shown in shaded grey.

Supplementary Figure 2: ***Change in lockdown stringency over study period among countries included in the iPOP Study****. Change in Oxford lockdown stringency index over lockdown study period, stratified by country.*

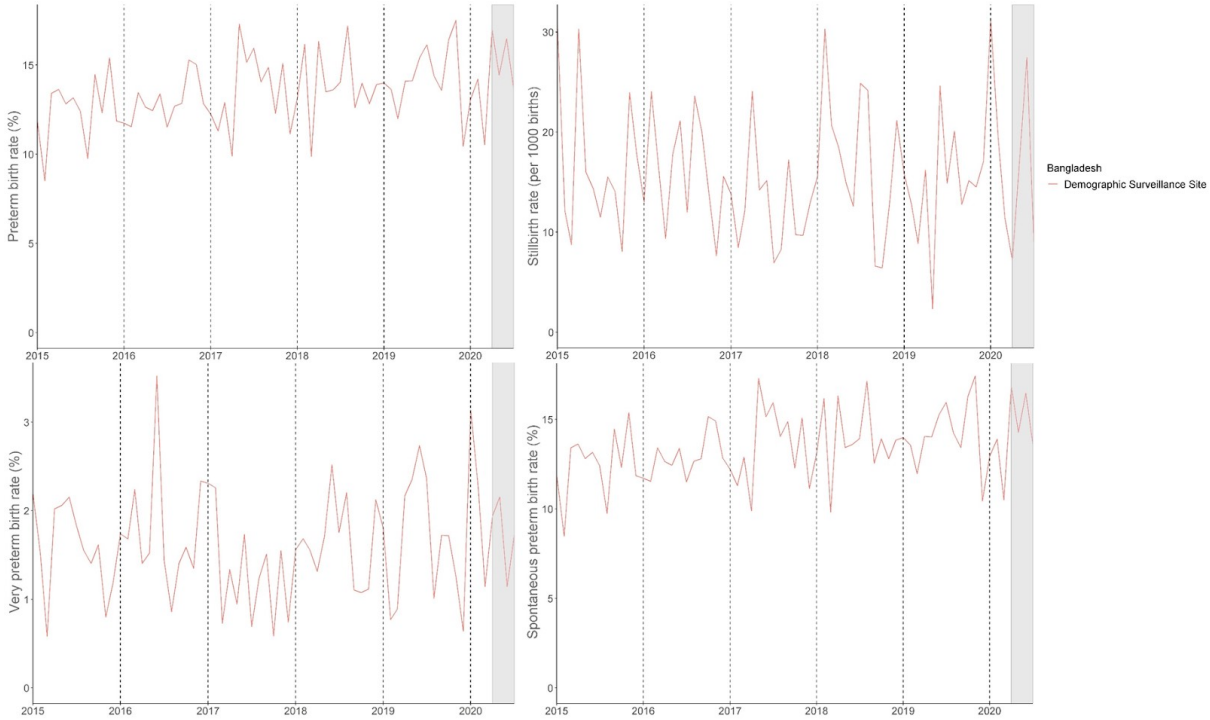
Dashed red line shows the stringency index of 50.

Preterm and stillbirth rates over time in non-population-based datasets



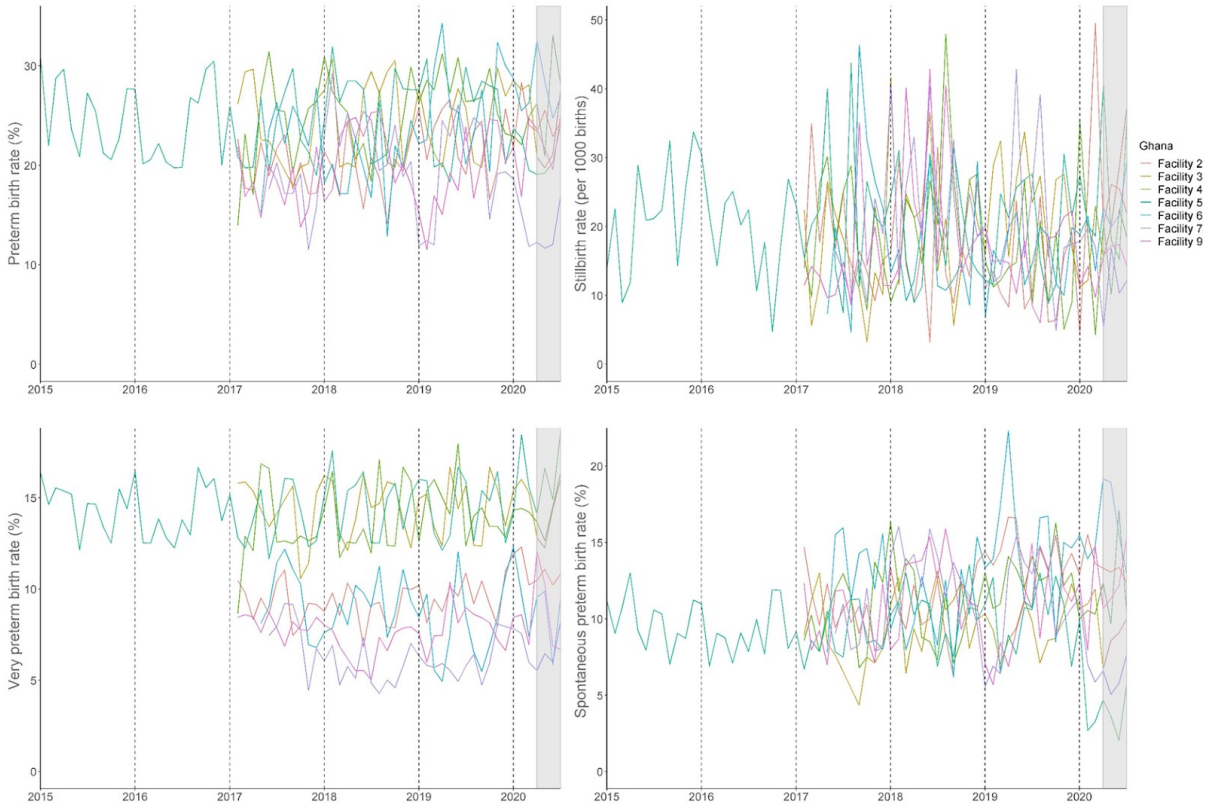
Supplementary Figure 3: Preterm birth rates, stillbirth rates, very preterm birth rates and spontaneous preterm birth rates among all births 22 weeks onwards over time in a non-population-based dataset from ***Queensland, Australia.***

Lockdown period shown in shaded grey.



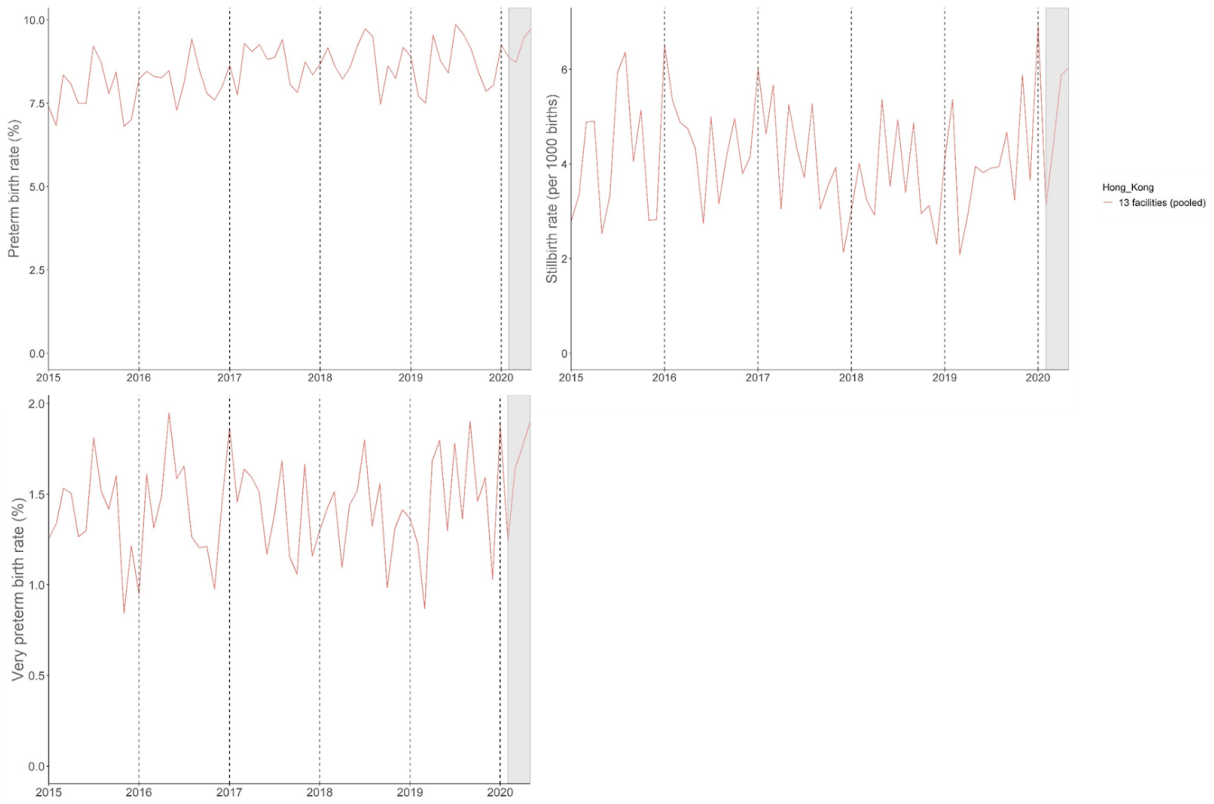
*Supplementary Figure 4: Preterm birth rates, very preterm birth rates and spontaneous preterm birth rates among all births 22 weeks onwards over time in a non-population-based dataset from **Matlab, Bangladesh**.*

Lockdown period shown in shaded grey.



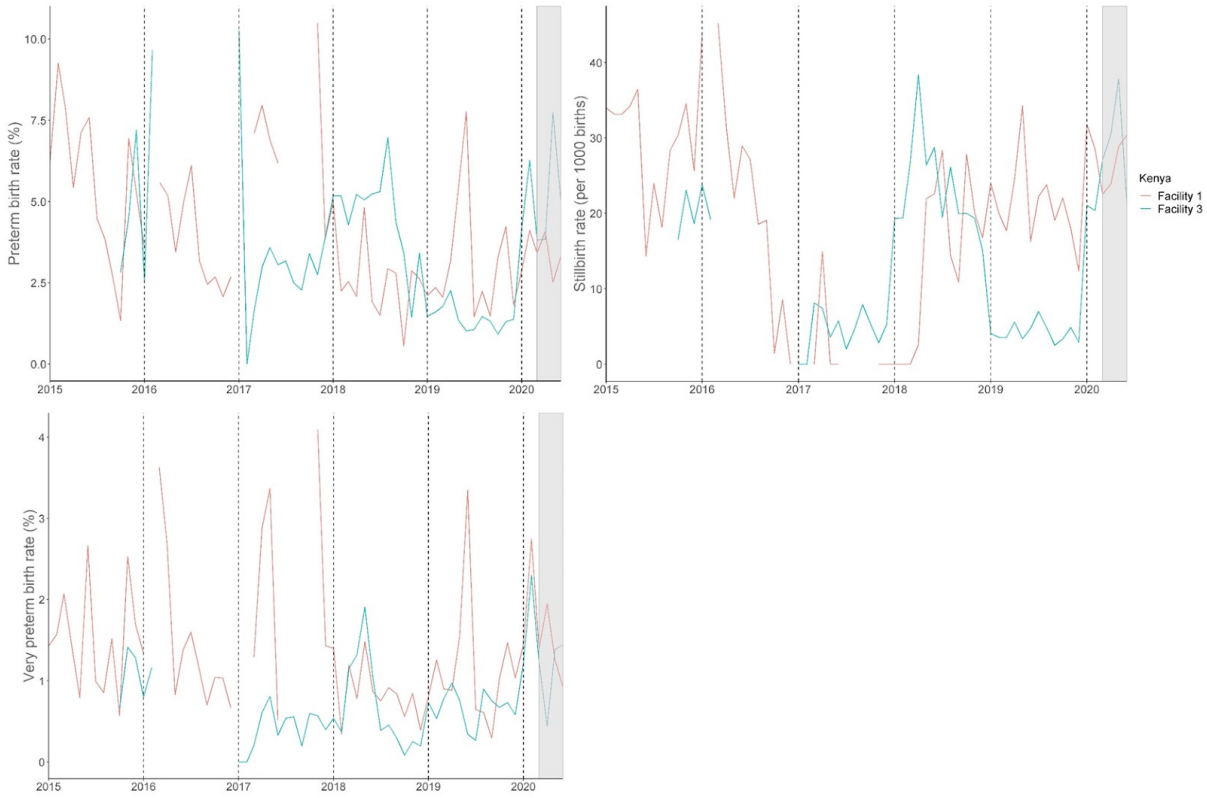
*Supplementary Figure 5: Preterm birth rates, stillbirth rates, very preterm birth rates and spontaneous preterm birth rates among all births 22 weeks onwards over time in non-population-based datasets from **Ghana**, stratified by facility.*

Lockdown period shown in shaded grey.



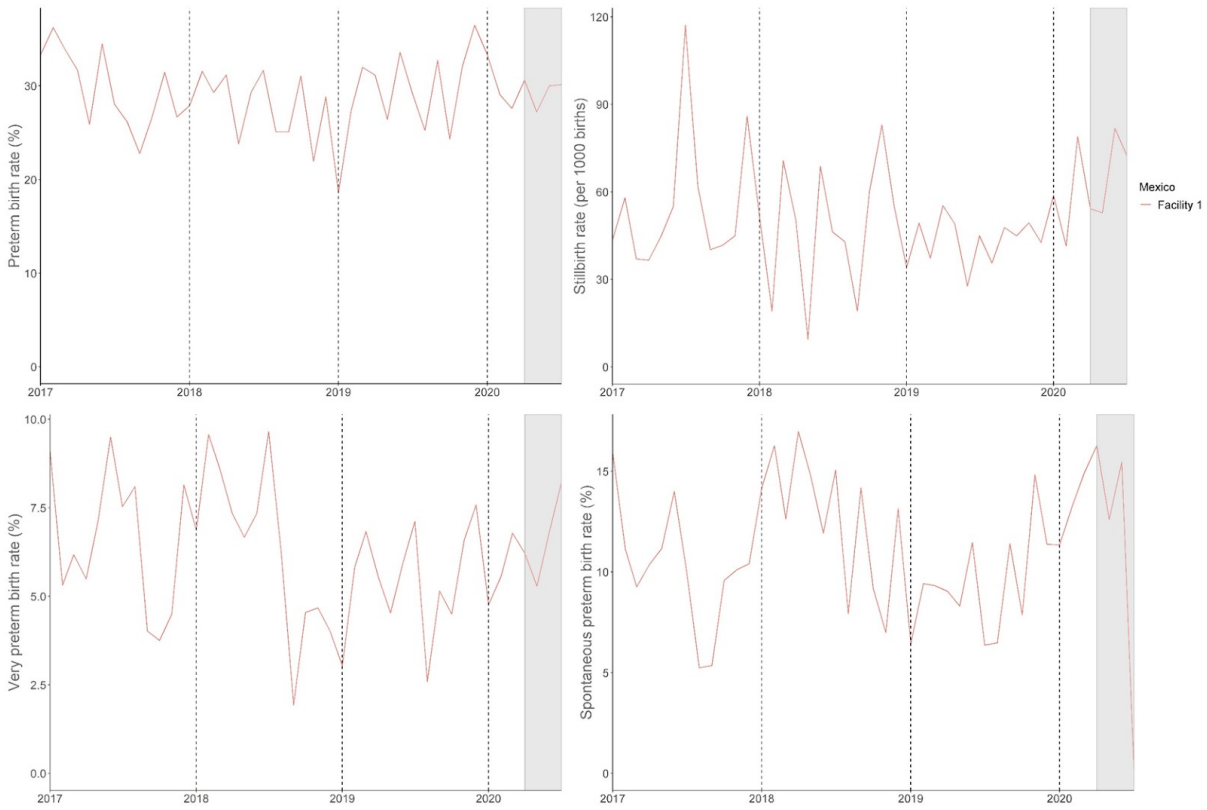
*Supplementary Figure 6: Preterm birth rates, stillbirth rate and very preterm birth rates among all births 22 weeks onwards over time in a non-population-based dataset from **Hong Kong**.*

Lockdown period shown in shaded grey.



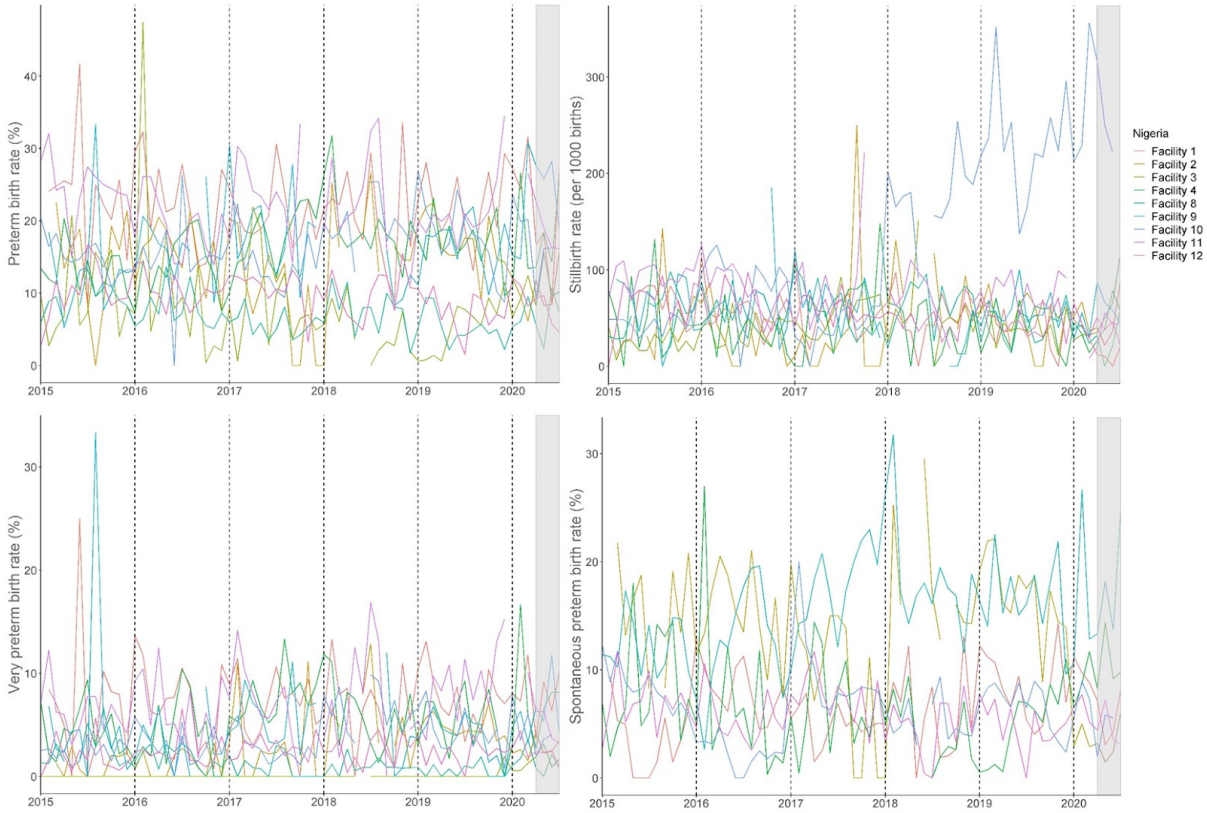
*Supplementary Figure 7: Preterm birth rates, stillbirth rate and very preterm birth rates among all births 22 weeks onwards over time in non-population-based datasets from **Kenya**, stratified by facility.*

Lockdown period shown in shaded grey.



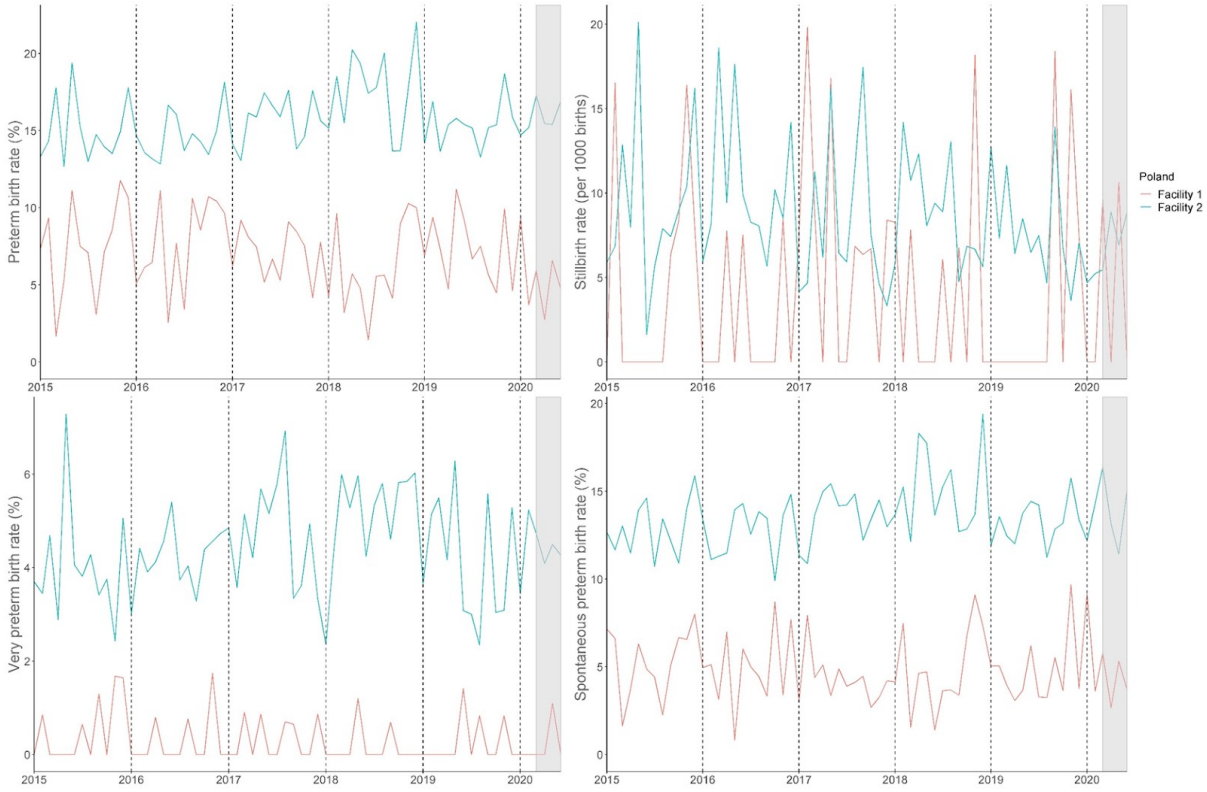
*Supplementary Figure 8: Preterm birth rates, stillbirth rates, very preterm birth rates and spontaneous preterm birth rates among all births 22 weeks onwards over time in a non-population-based dataset from **Mexico**.*

Lockdown period shown in shaded grey.



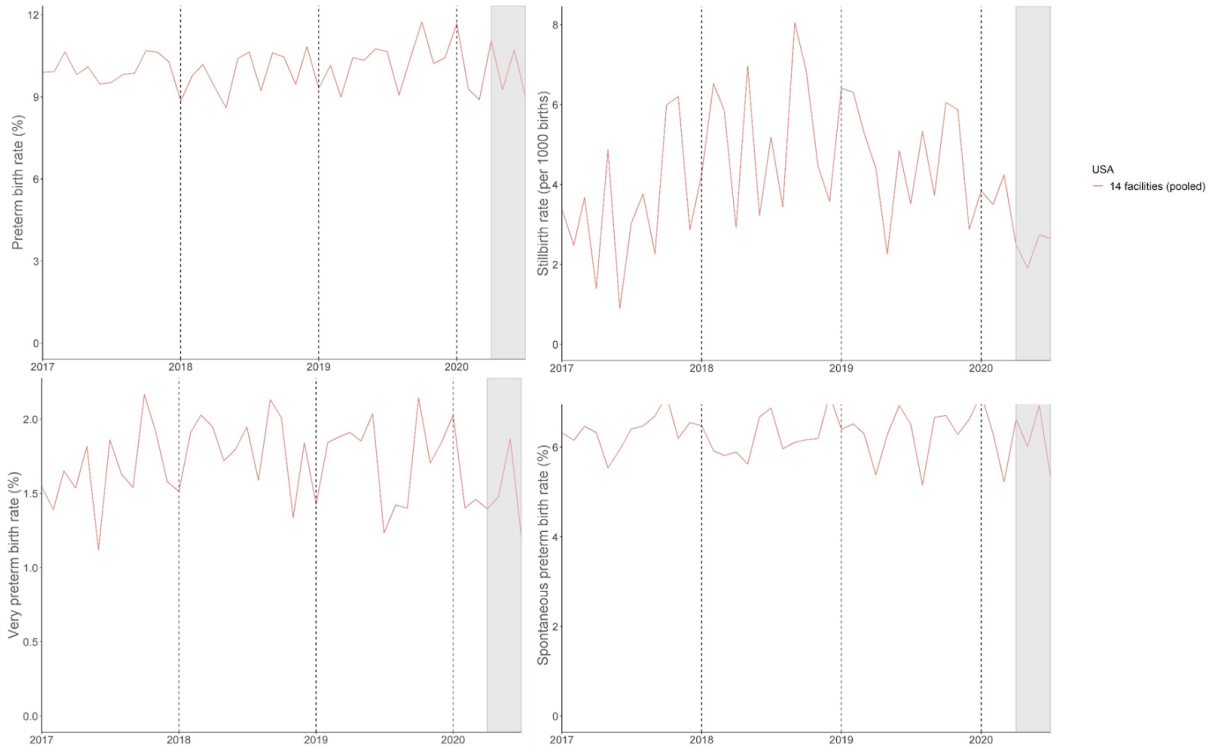
*Supplementary Figure 9: Preterm birth rates, stillbirth rates, very preterm birth rates and spontaneous preterm birth rates among all births 22 weeks onwards over time in non-population-based datasets from **Nigeria**, stratified by facility.*

Lockdown period shown in shaded grey.



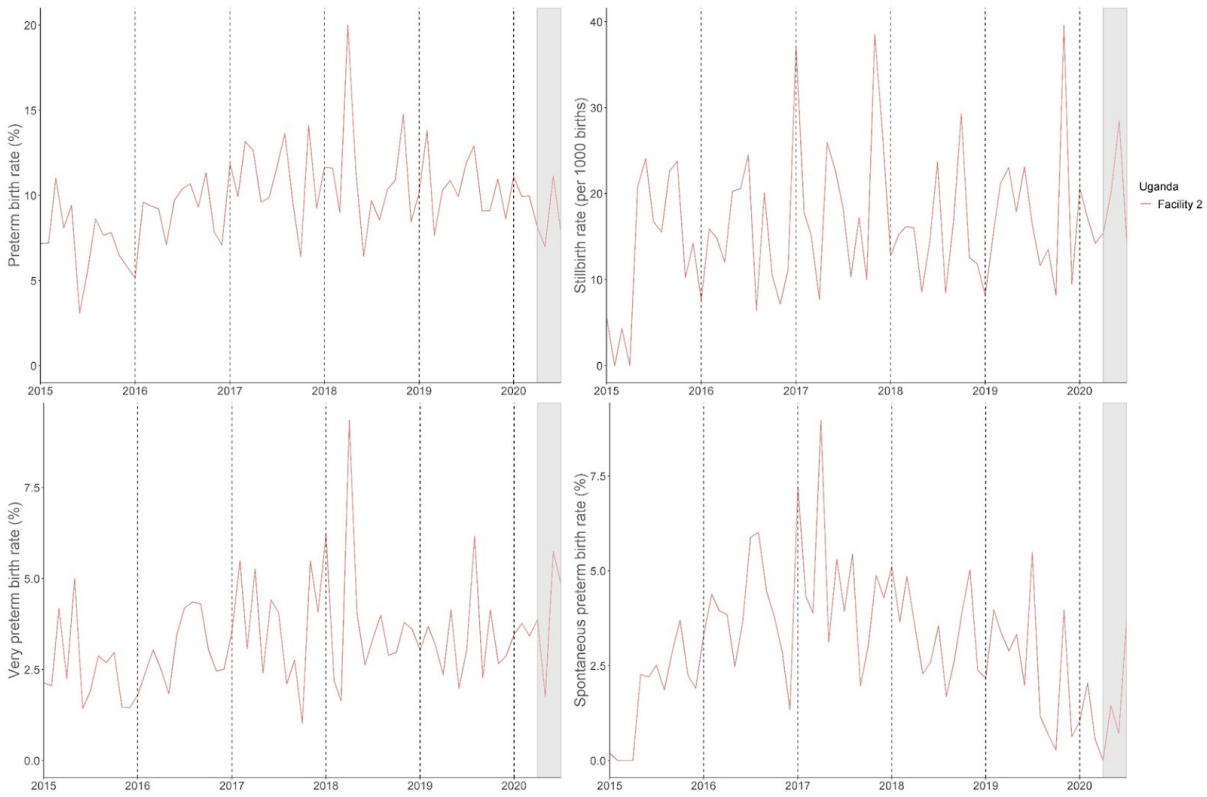
*Supplementary Figure 10: Preterm birth rates, stillbirth rates, very preterm birth rates and spontaneous preterm birth rates among all births 22 weeks onwards over time in non-population-based datasets from **Poland**, stratified by facility.*

Lockdown period shown in shaded grey.



*Supplementary Figure 11: Preterm birth rates, stillbirth rates, very preterm birth rates and spontaneous preterm birth rates among all births 22 weeks onwards over time in a non-population-based dataset from **Washington State, USA**.*

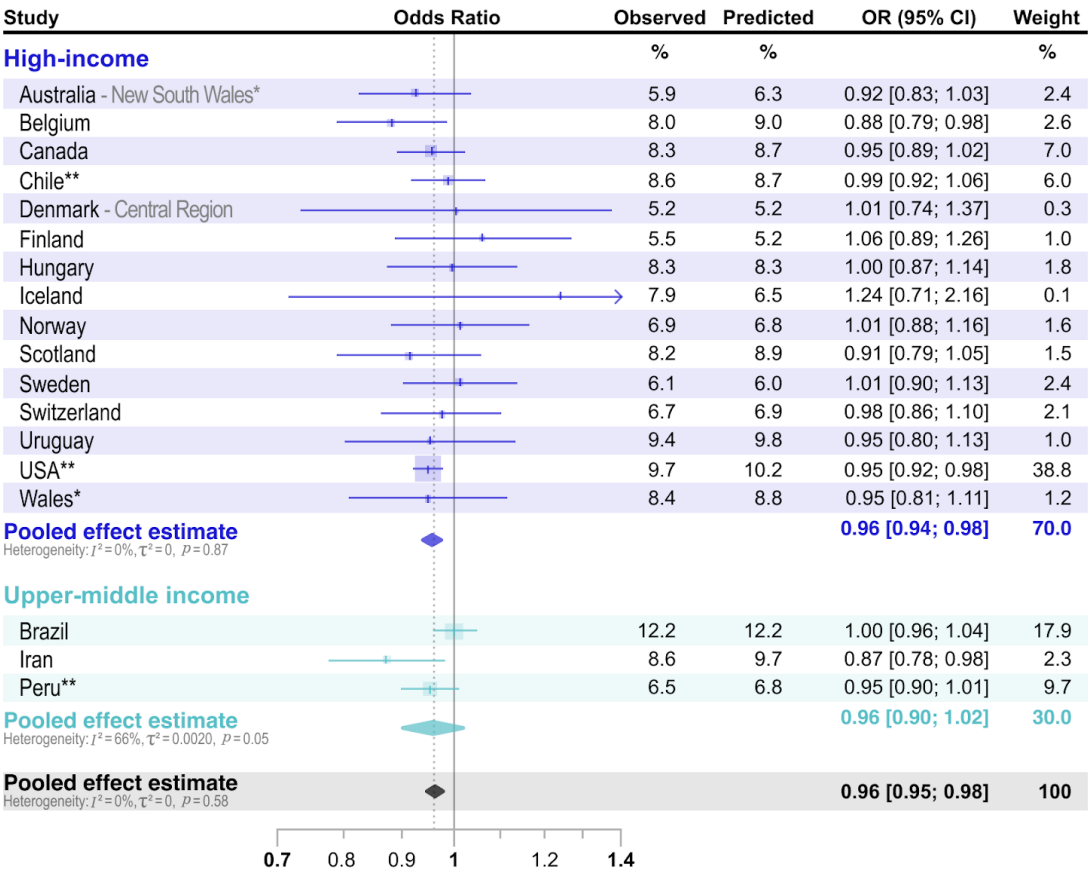
Lockdown period shown in shaded grey.



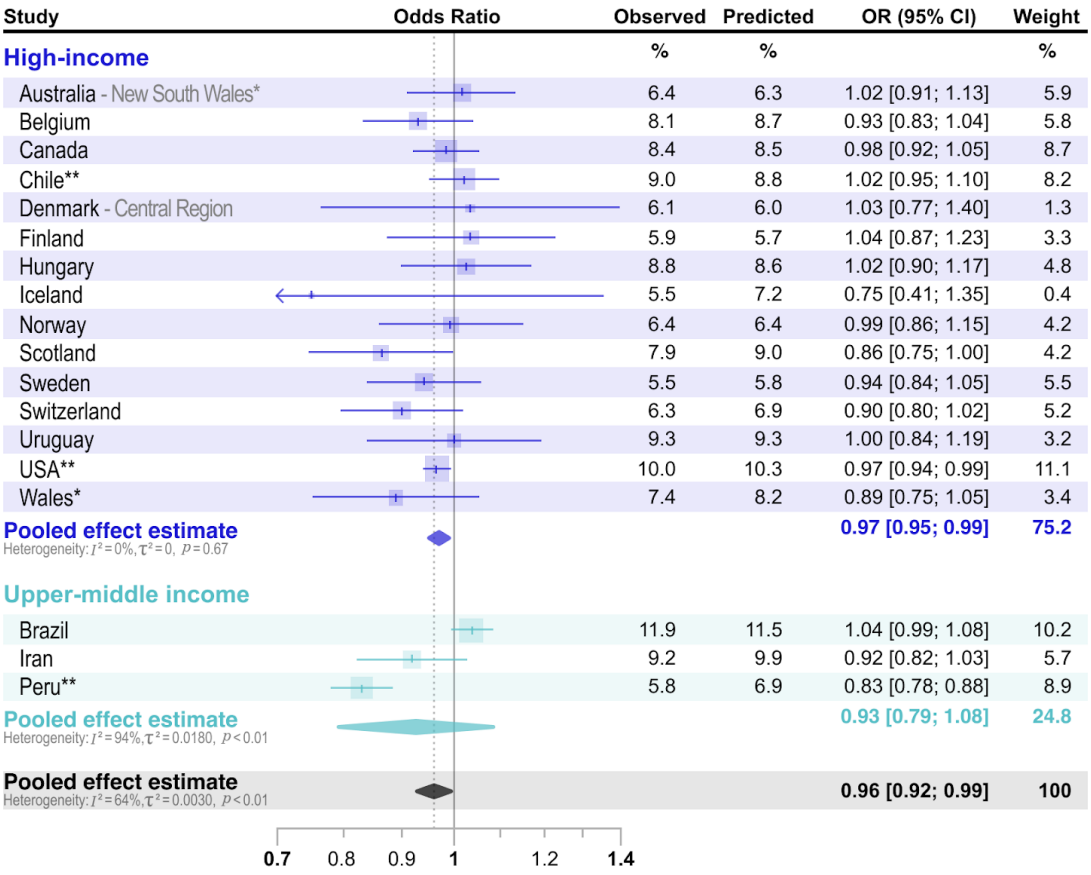
Supplementary Figure 12: Preterm birth rates, stillbirth rates, very preterm birth rates and spontaneous preterm birth rates among all births 22 weeks onwards over time in non-population-based datasets from ***Uganda****.*

Lockdown period shown in shaded grey.

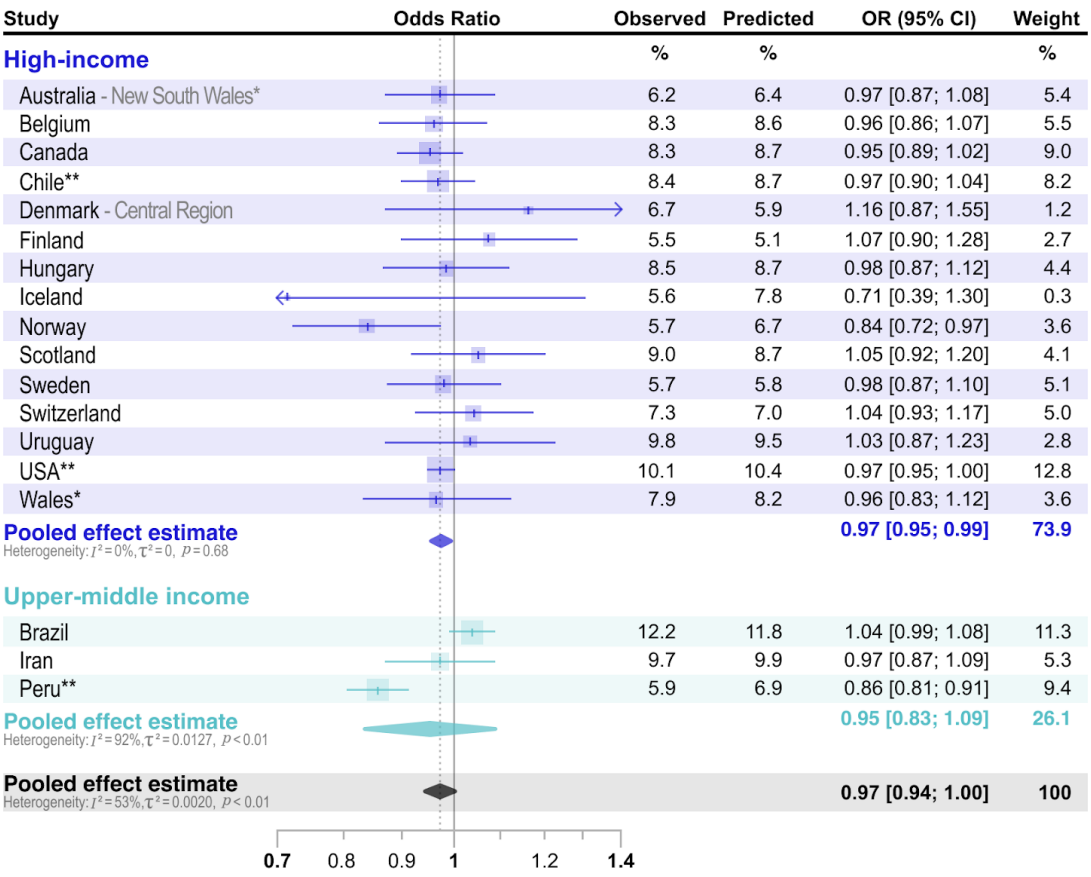
Association between lockdown and preterm birth rates, by time since lockdown



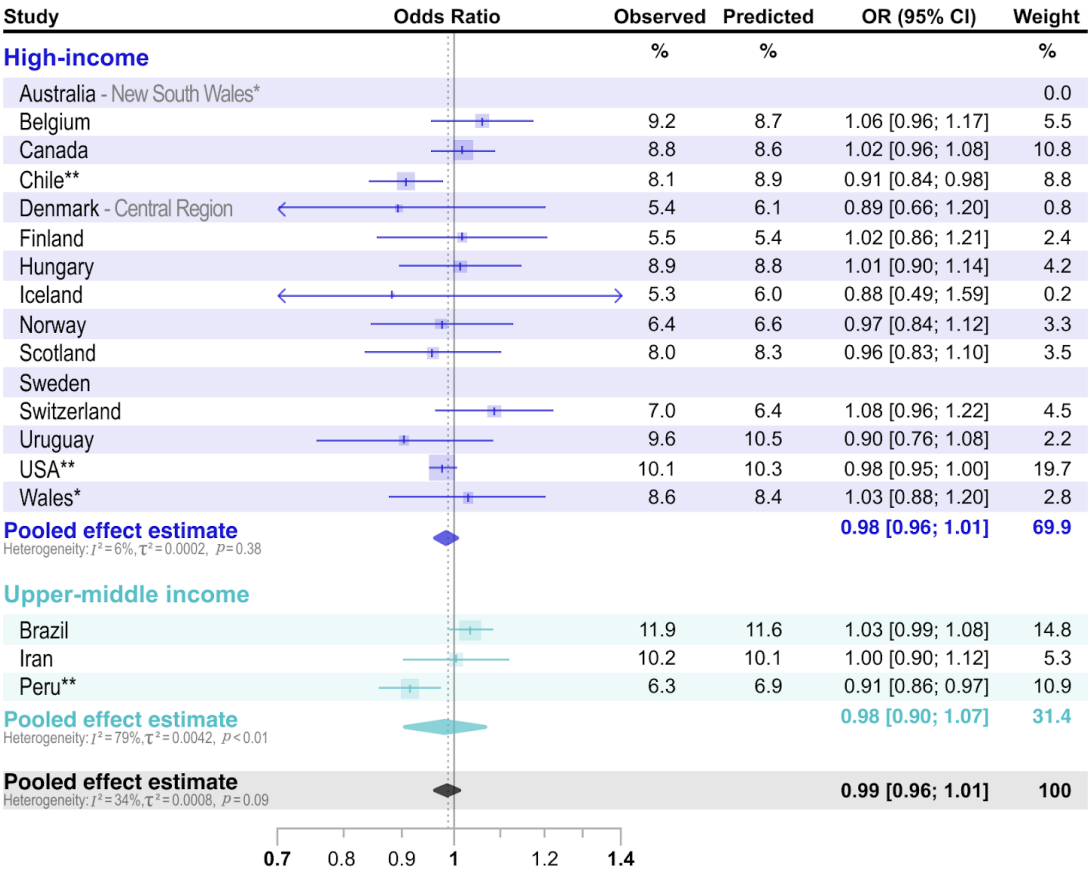
*Supplementary Figure 13: Individual and pooled **population-based estimates** of the association between lockdown and the odds of **preterm birth** among all births 22 weeks onwards, in the **first month** of lockdown. Individual country odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of preterm birth in the first month of lockdown to the forecasted odds of preterm birth in the first month of lockdown from an interrupted time series model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each country provided in Table 1. *Births from 24 weeks onwards; **Live births only*



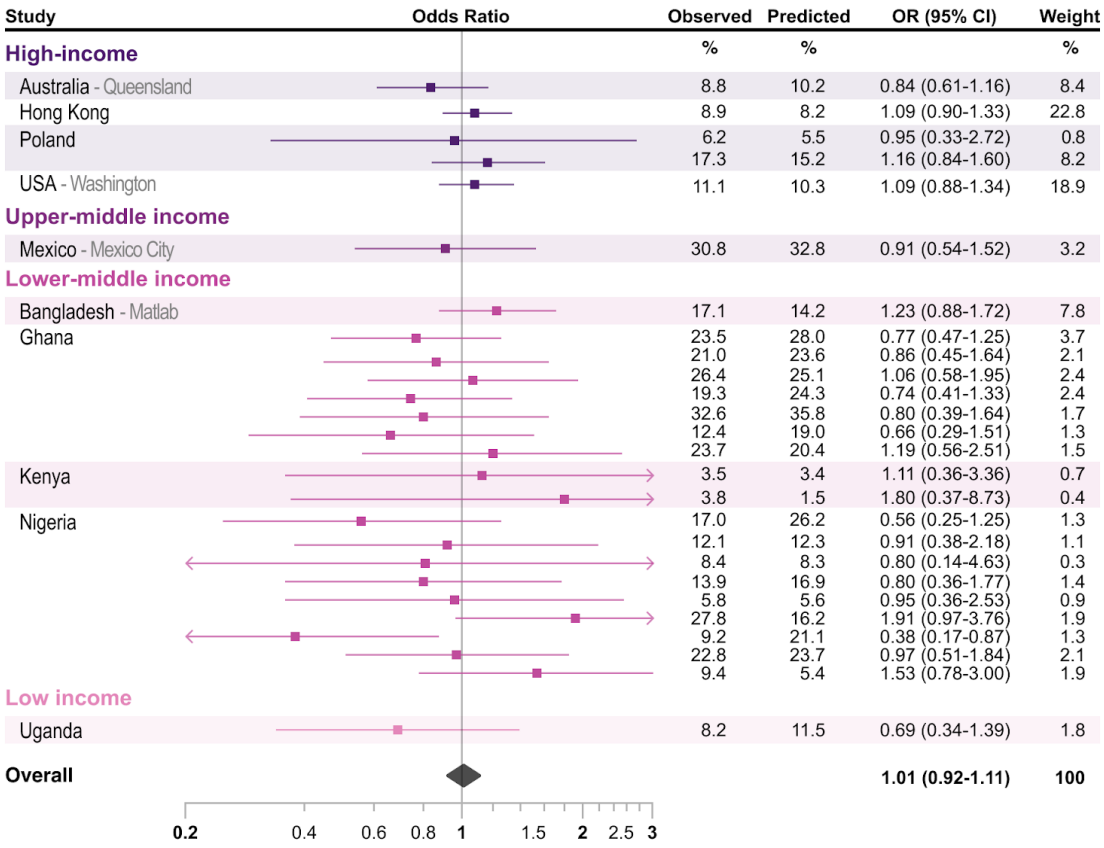
*Supplementary Figure 14: Individual and pooled **population-based estimates** of the association between lockdown and the odds of **preterm birth** among all births 22 weeks onwards, in the **second month** of lockdown. Individual country odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of preterm birth in the second month of lockdown to the forecasted odds of preterm birth in the second month of lockdown from an interrupted time series model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each country provided in Table 1.*Births from 24 weeks onwards; **Live births only*



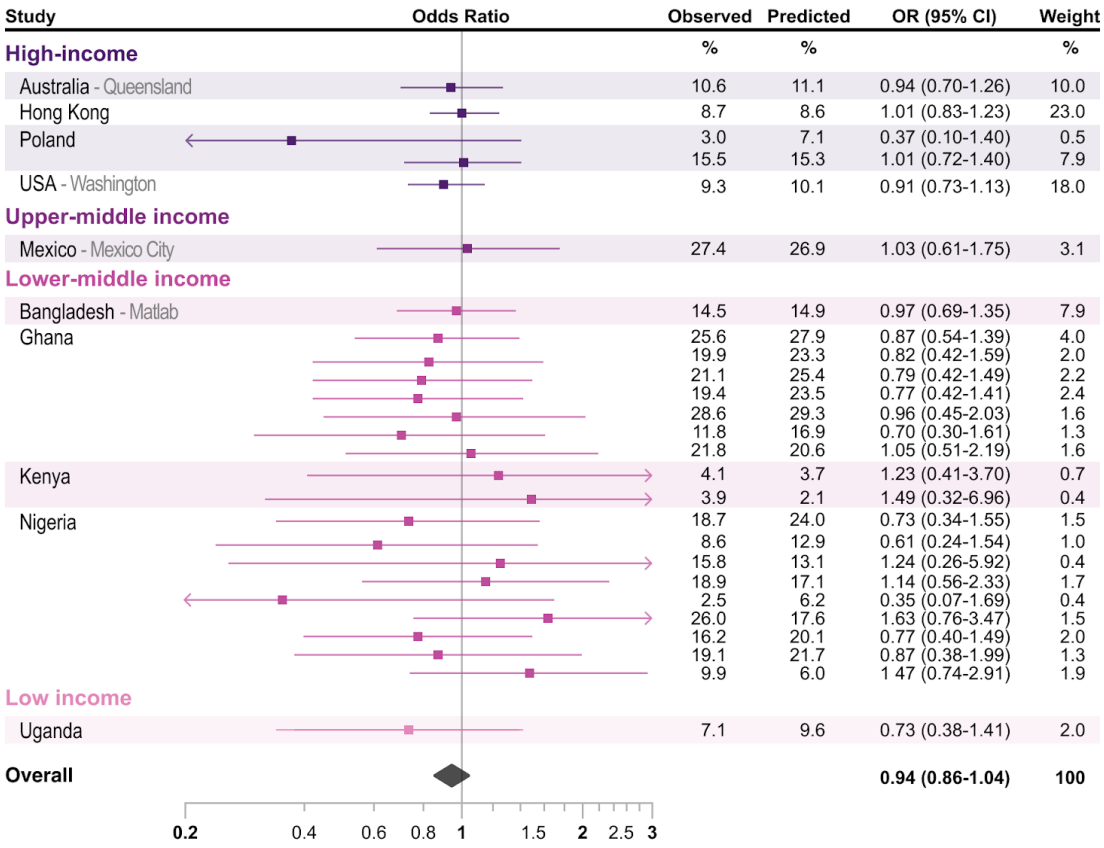
*Supplementary Figure 15: Individual and pooled **population-based estimates** of the association between lockdown and the odds of **preterm birth** among all births 22 weeks onwards, in the **third month** of lockdown. Individual country odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of preterm birth in the third month of lockdown to the forecasted odds of preterm birth in the third month of lockdown from an interrupted time series model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each country provided in Table 1. *Births from 24 weeks onwards; **Live births only*



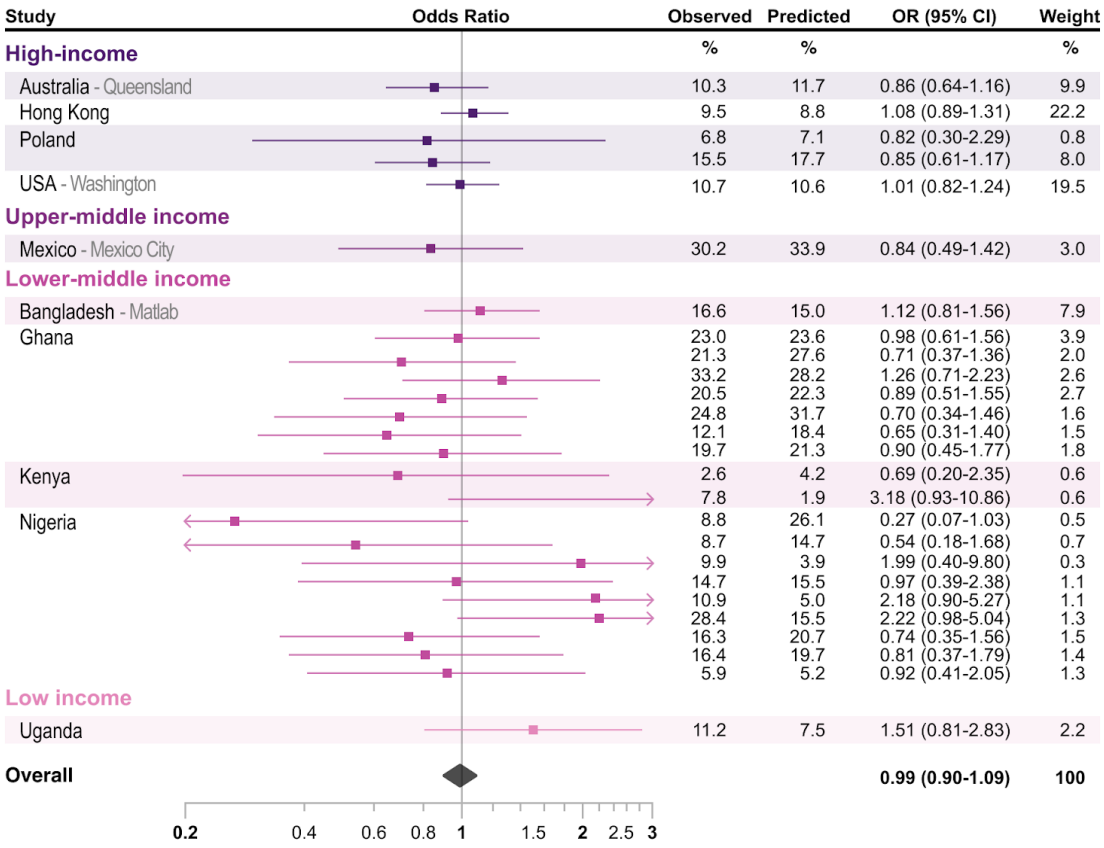
*Supplementary Figure 16: Individual and pooled **population-based estimates** of the association between lockdown and the odds of **preterm birth** among all births 22 weeks onwards, in the **fourth month** of lockdown. Individual country odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of preterm birth in the fourth month of lockdown to the forecasted odds of preterm birth in the fourth month of lockdown from an interrupted time series model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each country provided in Table 1.*Births from 24 weeks onwards; **Live births only*



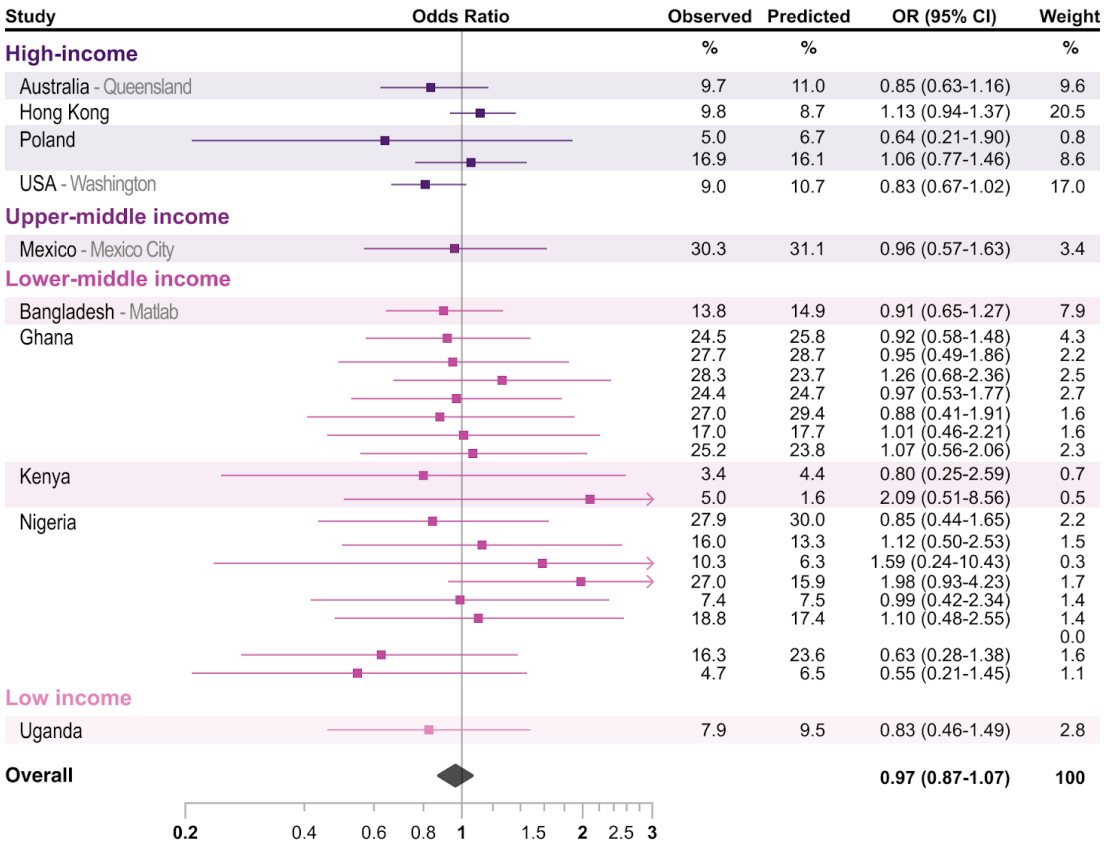
Supplementary Figure 17: Individual and pooled non-population-based estimates of the association between lockdown and the odds of preterm birth among all births 22 weeks onwards, in the first month of lockdown. Individual dataset odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of preterm birth in the first month of lockdown to the forecasted odds of preterm birth in the first month of lockdown from a linear regression model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each dataset provided in Table 2.



*Supplementary Figure 18: Individual and pooled **non-population-based estimates** of the association between lockdown and the odds of **preterm birth** among all births 22 weeks onwards, in the **second month** of lockdown. Individual dataset odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of preterm birth in the second month of lockdown to the forecasted odds of preterm birth in the second month of lockdown from a linear regression model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each dataset provided in Table 2.*

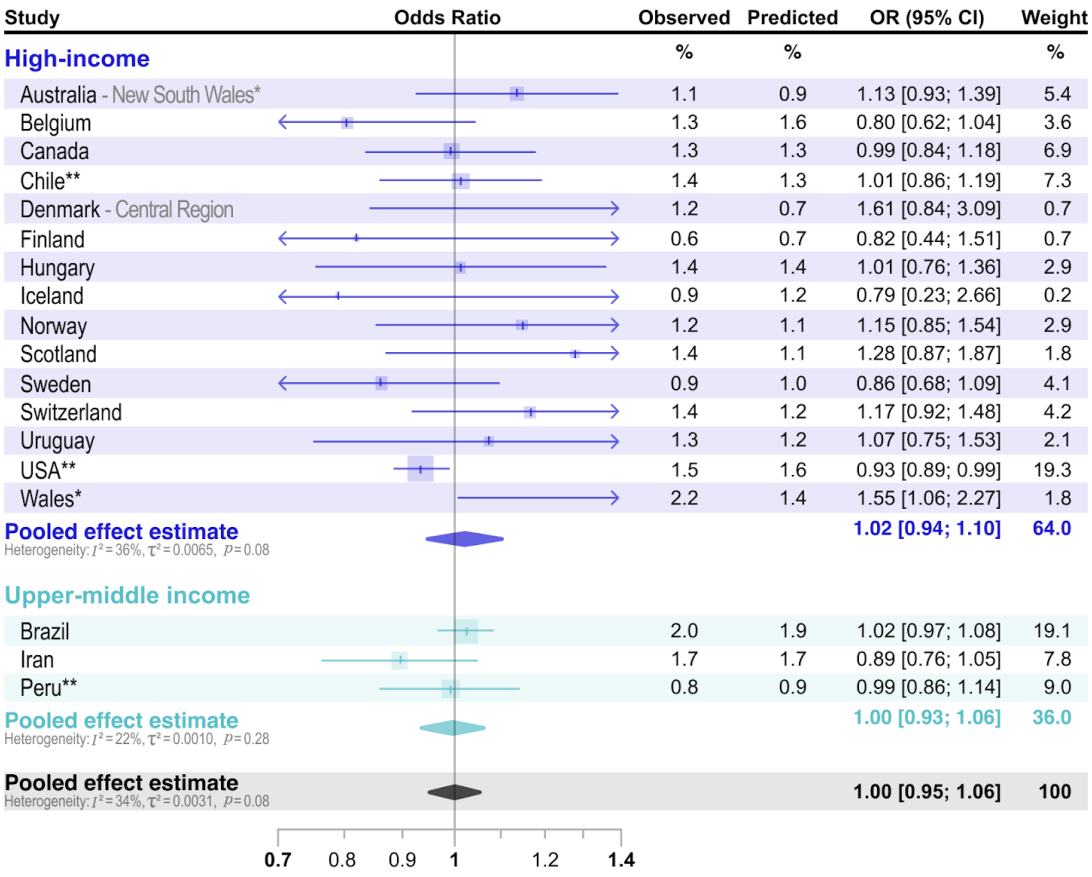


*Supplementary Figure 19: Individual and pooled **non-population-based estimates** of the association between lockdown and the odds of **preterm birth** among all births 22 weeks onwards, in the **third month** of lockdown. Individual dataset odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of preterm birth in the third month of lockdown to the forecasted odds of preterm birth in the third month of lockdown from a linear regression model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each dataset provided in Table 2.*

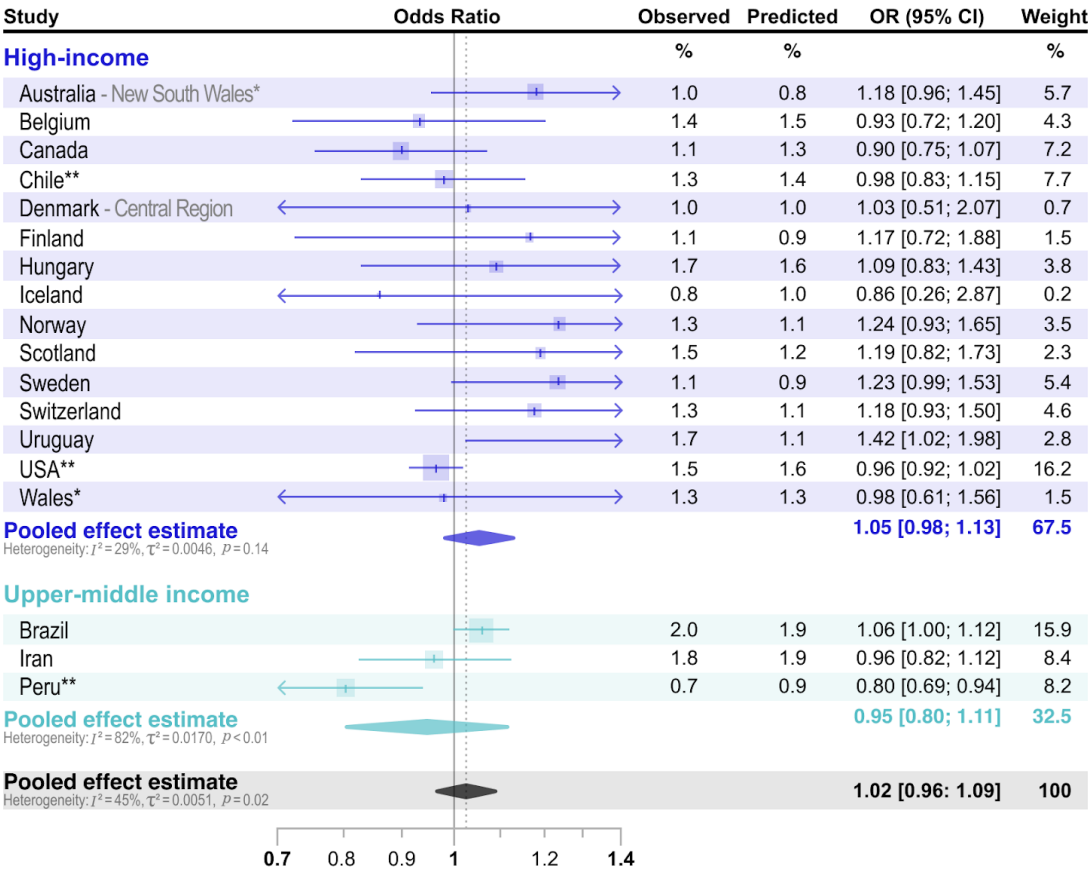


*Supplementary Figure 20: Individual and pooled **non-population-based estimates** of the association between lockdown and the odds of **preterm birth** among all births 22 weeks onwards, in the **fourth month** of lockdown. Individual dataset odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of preterm birth in the fourth month of lockdown to the forecasted odds of preterm birth in the fourth month of lockdown from a linear regression model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each dataset provided in Table 2.*

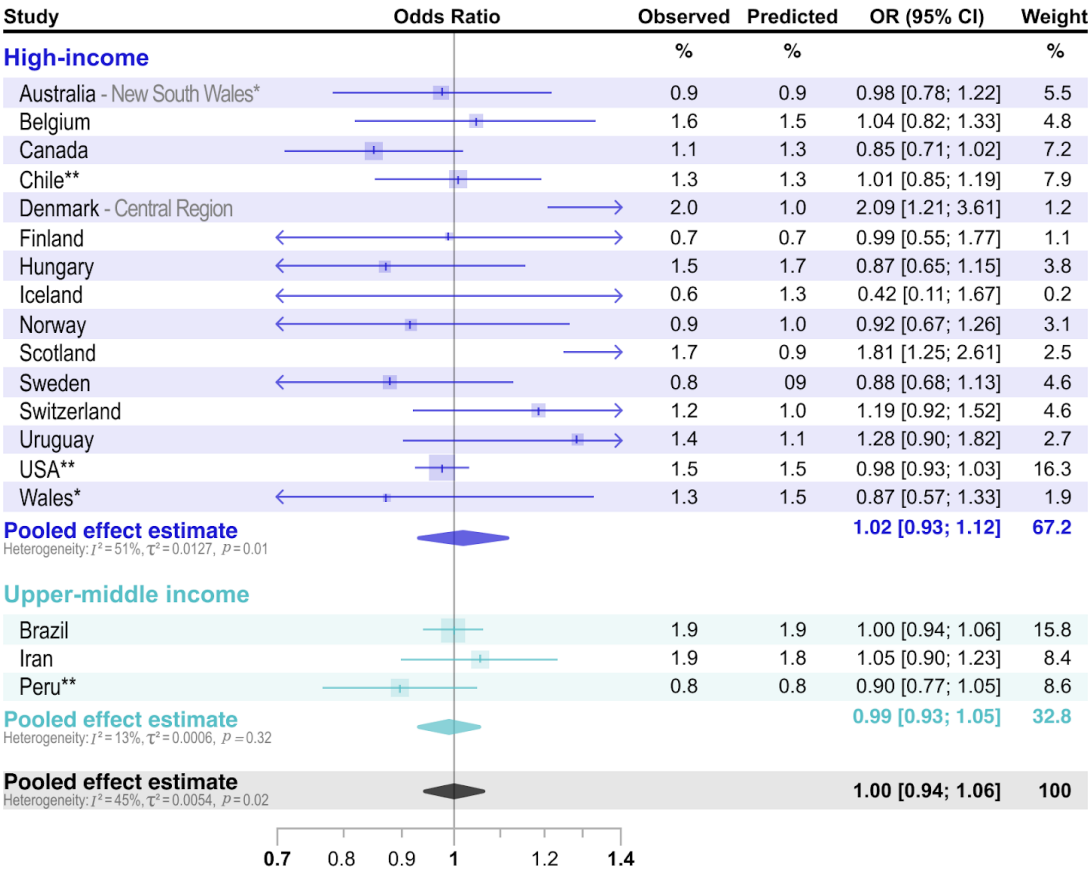
Association between lockdown and very preterm birth rates, by time since



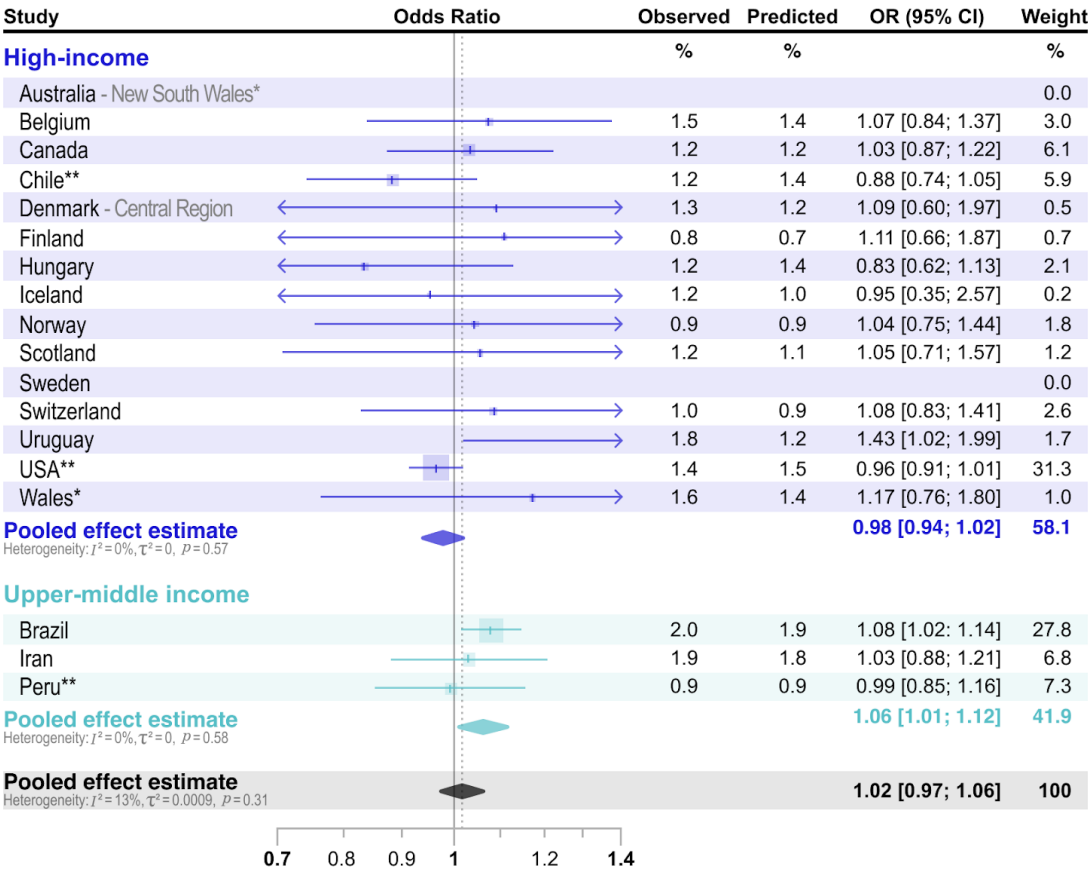
*Supplementary Figure 21: Individual and pooled **population-based estimates** of the association between lockdown and the odds of **very preterm birth** among all births 22 weeks onwards, in the **first month** of lockdown. Individual country odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of very preterm birth in the first month of lockdown to the forecasted odds of very preterm birth in the first month of lockdown from an interrupted time series model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each country provided in Table 1. *Births from 24 weeks onwards; **Live births only*



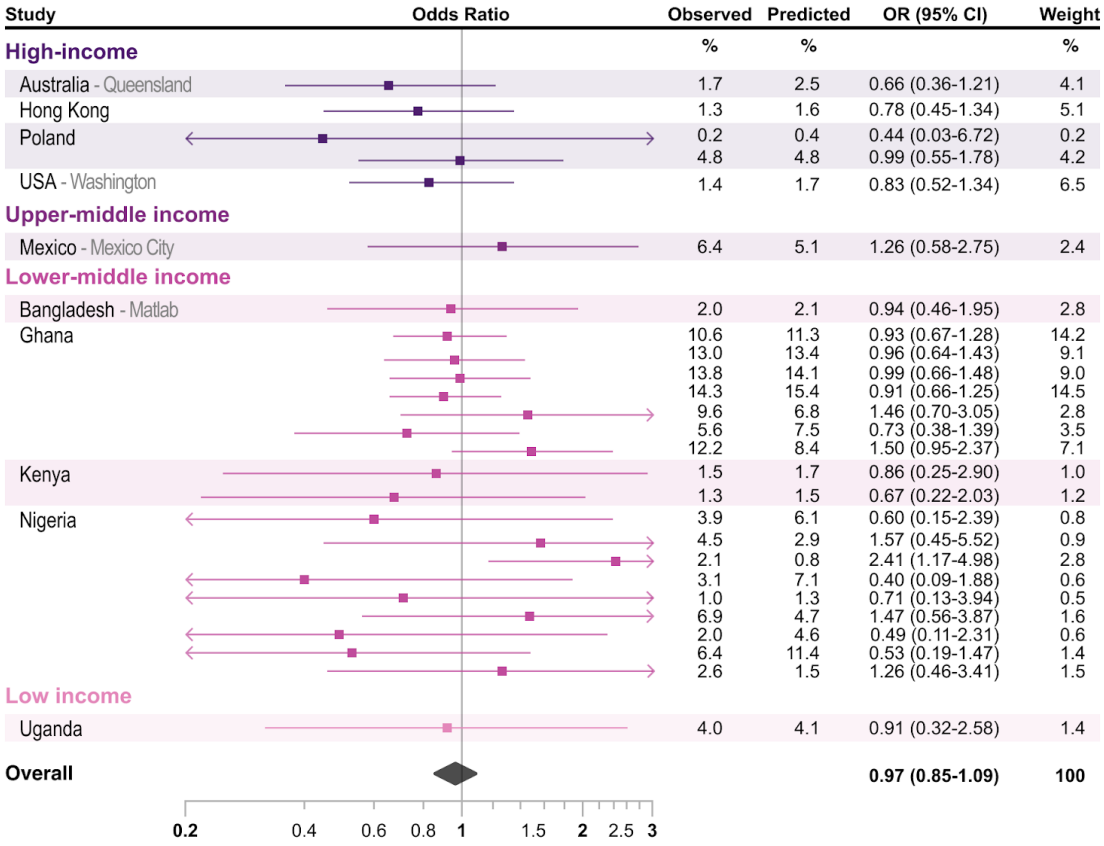
*Supplementary Figure 22: Individual and pooled **population-based estimates** of the association between lockdown and the odds of **very preterm birth** among all births 22 weeks onwards, in the **second month** of lockdown. Individual country odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of very preterm birth in the second month of lockdown to the forecasted odds of very preterm birth in the second month of lockdown from an interrupted time series model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each country provided in Table 1. *Births from 24 weeks onwards; **Live births only*



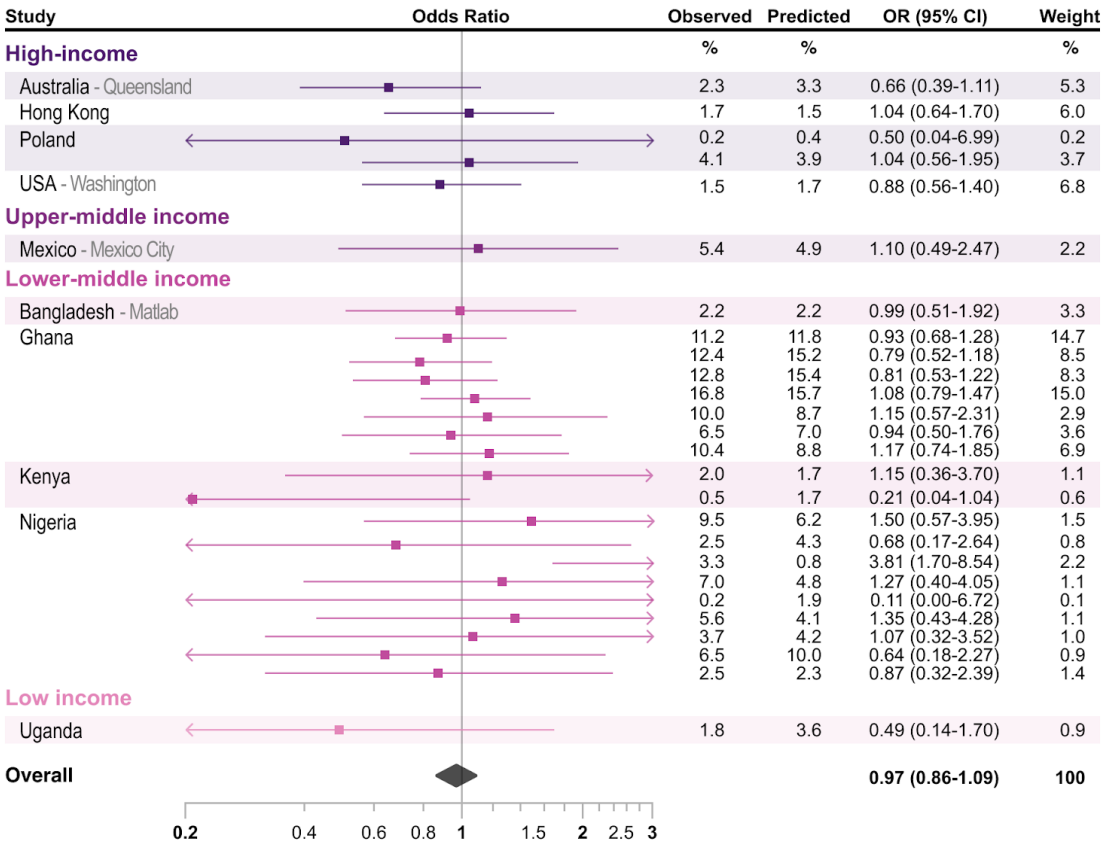
*Supplementary Figure 23: Individual and pooled **population-based estimates** of the association between lockdown and the odds of **very preterm birth** among all births 22 weeks onwards, in the **third month** of lockdown. Individual country odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of very preterm birth in the third month of lockdown to the forecasted odds of very preterm birth in the third month of lockdown from an interrupted time series model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each country provided in Table 1. *Births from 24 weeks onwards; **Live births only*



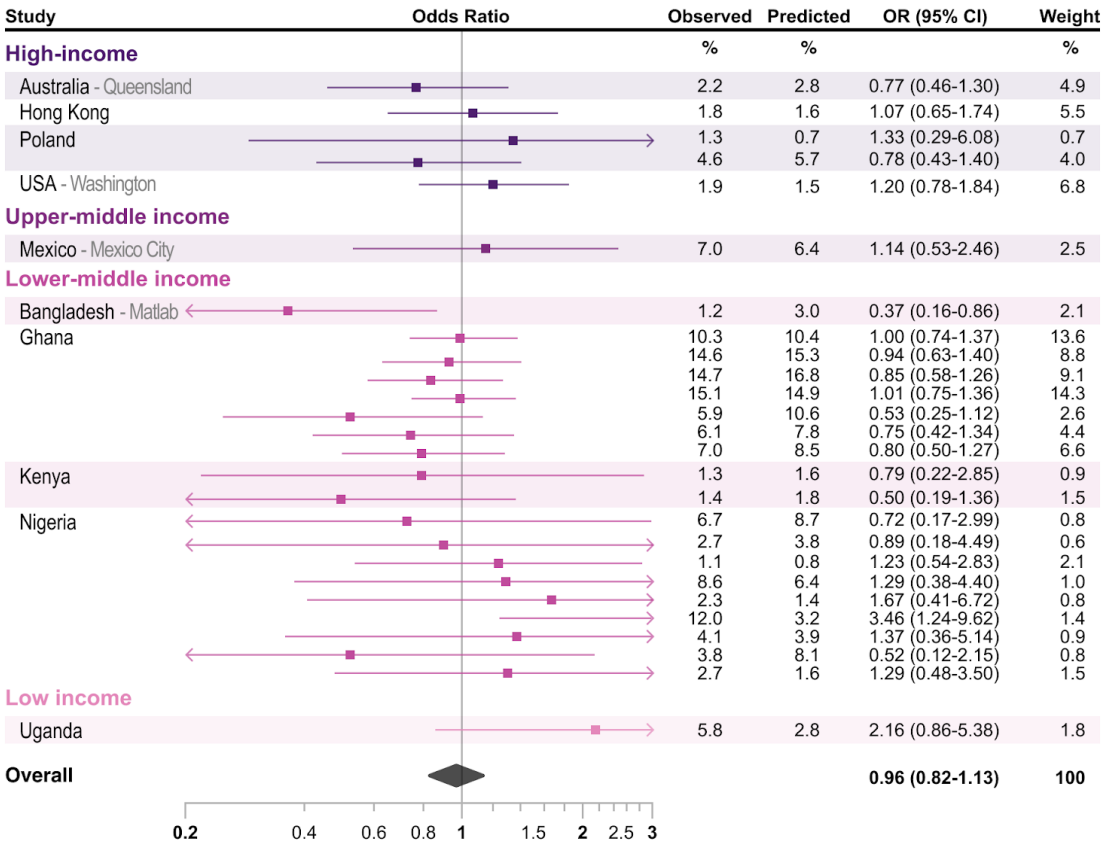
*Supplementary Figure 24: Individual and pooled **population-based estimates** of the association between lockdown and the odds of **very preterm birth** among all births 22 weeks onwards, in the **fourth month** of lockdown. Individual country odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of very preterm birth in the fourth month of lockdown to the forecasted odds of very preterm birth in the fourth month of lockdown from an interrupted time series model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each country provided in Table 1. *Births from 24 weeks onwards; **Live births only*



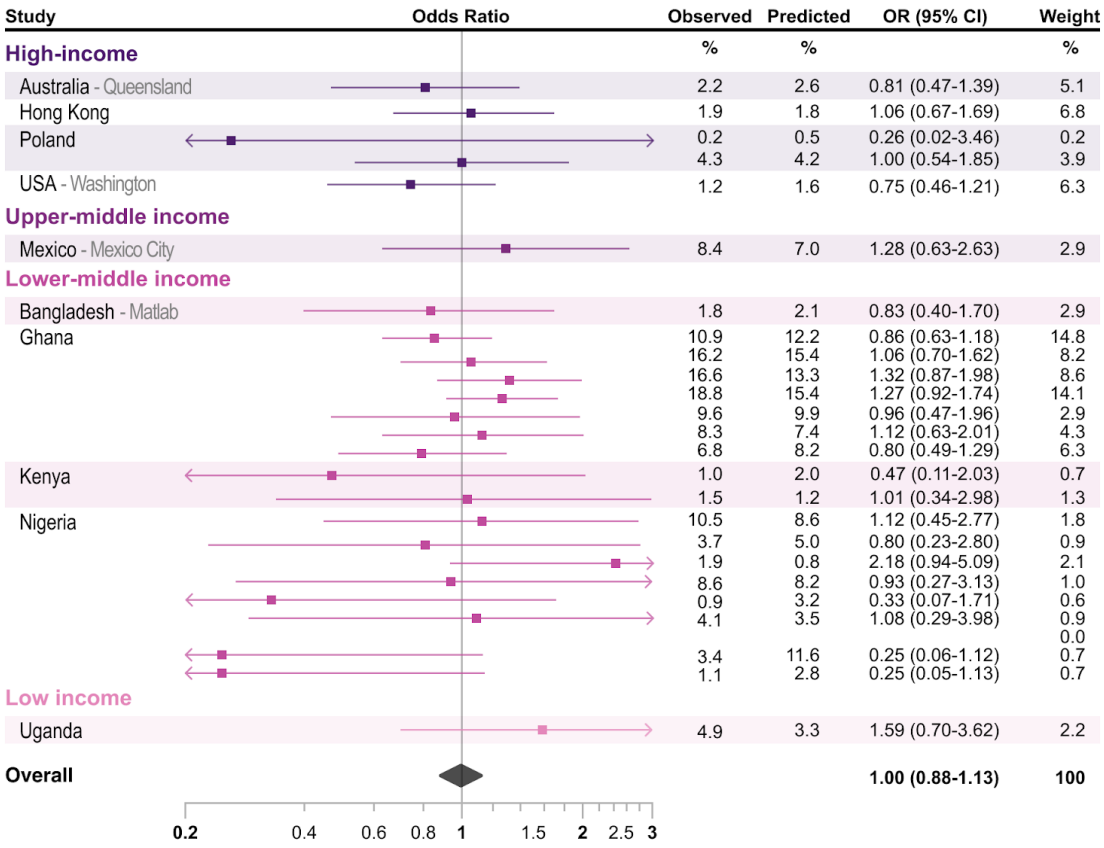
*Supplementary Figure 25: Individual and pooled **non-population-based estimates** of the association between lockdown and the odds of **very preterm birth** among all births 22 weeks onwards, in the **first month** of lockdown. Individual dataset odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of very preterm birth in the first month of lockdown to the forecasted odds of very preterm birth in the first month of lockdown from a linear regression model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each dataset provided in Table 2.*



*Supplementary Figure 26: Individual and pooled **non-population-based estimates** of the association between lockdown and the odds of **very preterm birth** among all births 22 weeks onwards, in the **second month** of lockdown. Individual dataset odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of very preterm birth in the second month of lockdown to the forecasted odds of very preterm birth in the second month of lockdown from a linear regression model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each dataset provided in Table 2.*

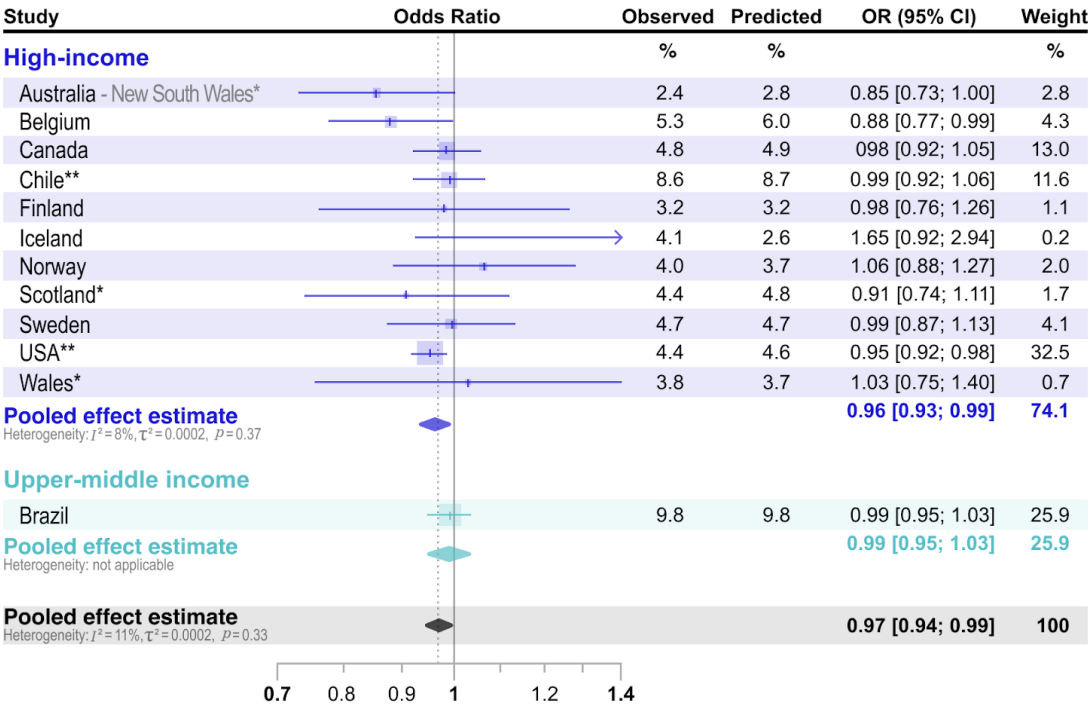


*Supplementary Figure 27: Individual and pooled **non-population-based estimates** of the association between lockdown and the odds of **very preterm birth** among all births 22 weeks onwards, in the **third month** of lockdown. Individual dataset odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of very preterm birth in the third month of lockdown to the forecasted odds of very preterm birth in the third month of lockdown from a linear regression model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each dataset provided in Table 2.*

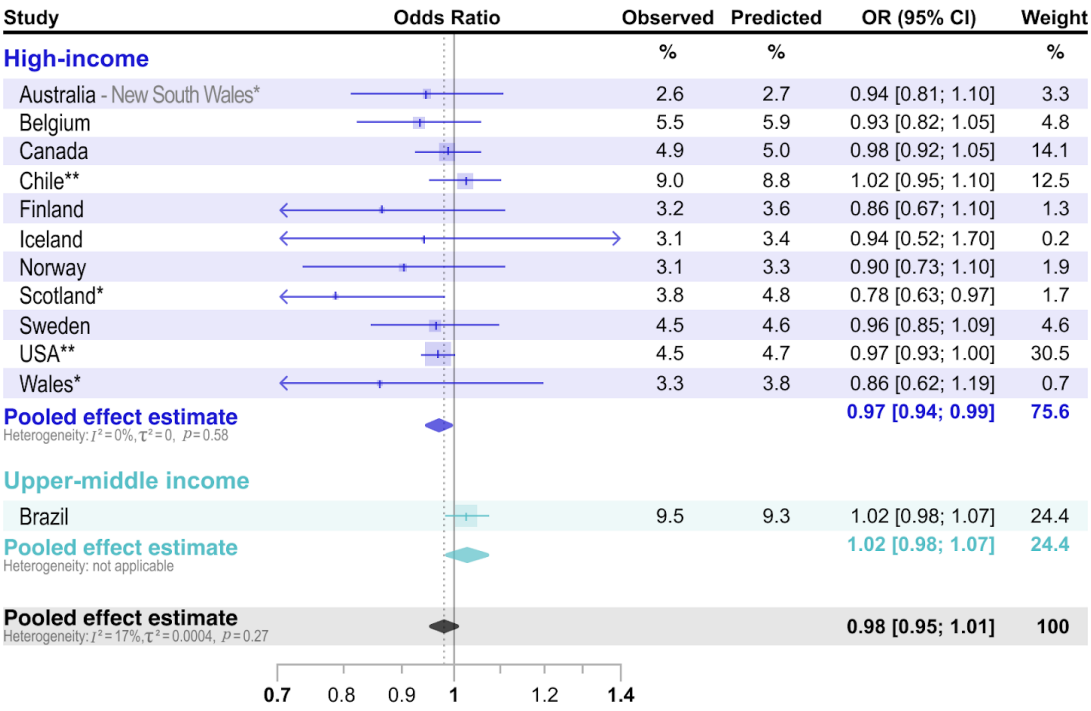


*Supplementary Figure 28: Individual and pooled **non-population-based estimates** of the association between lockdown and the odds of **very preterm birth** among all births 22 weeks onwards, in the **fourth month** of lockdown. Individual dataset odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of very preterm birth in the fourth month of lockdown to the forecasted odds of very preterm birth in the fourth month of lockdown from a linear regression model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each dataset provided in Table 2.*

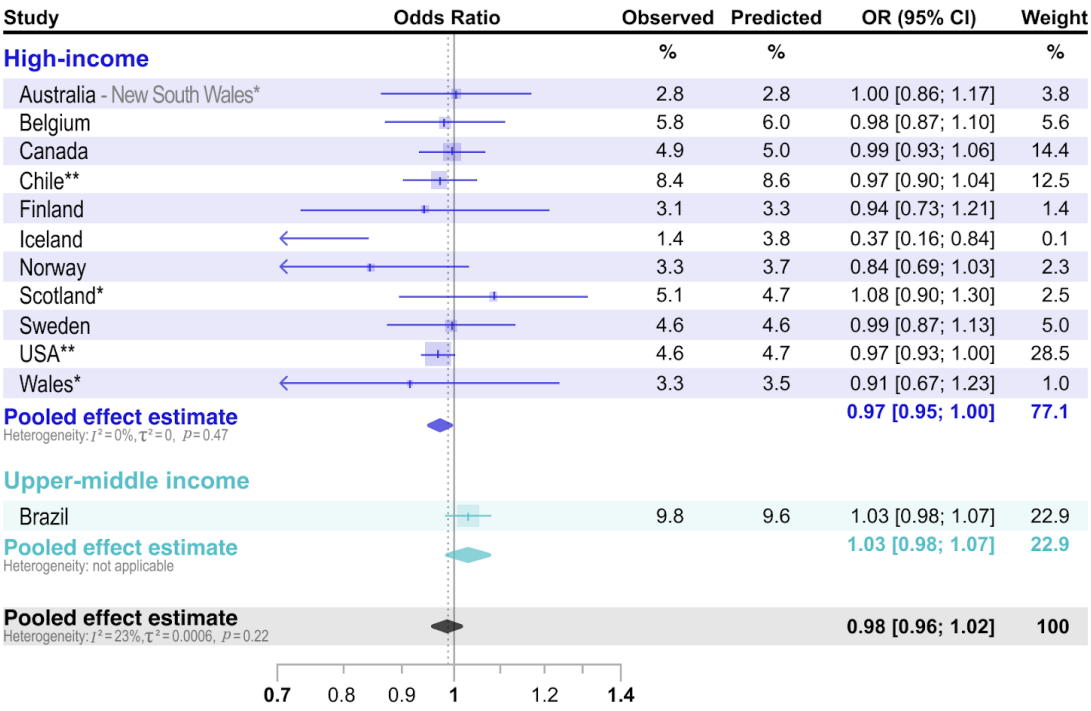
Association between lockdown and spontaneous preterm birth rates, by time since lockdown



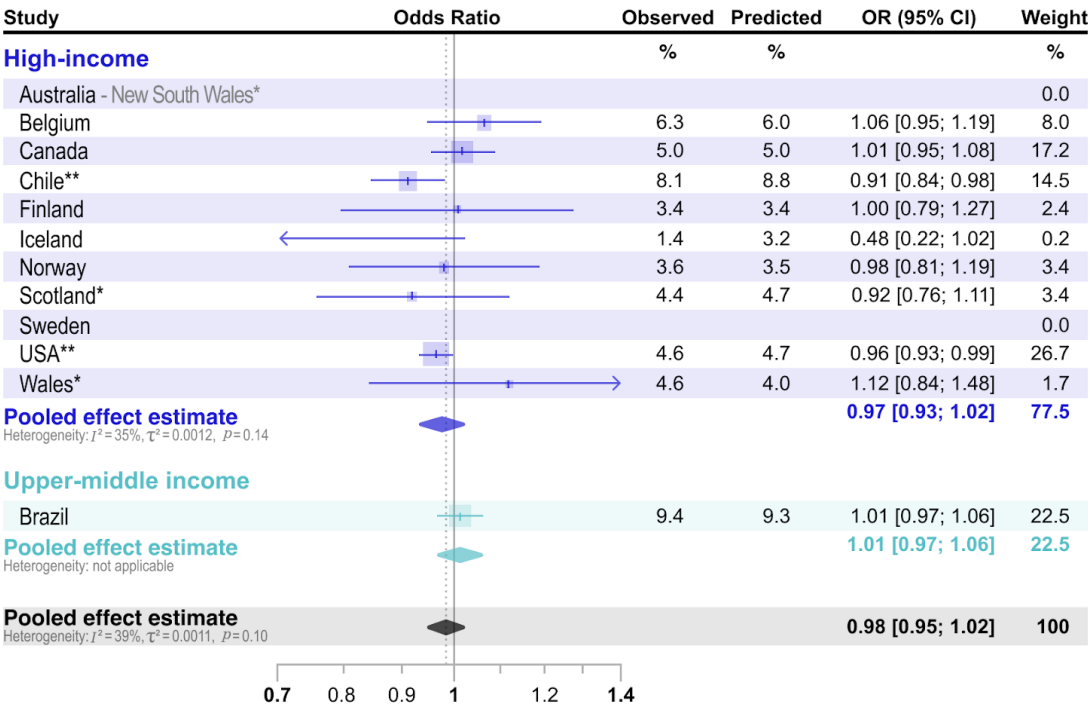
*Supplementary Figure 29: Individual and pooled **population-based estimates** of the association between lockdown and the odds of **spontaneous preterm birth** among all births 22 weeks onwards, in the **first month** of lockdown. Individual country odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of spontaneous preterm birth in the first month of lockdown to the forecasted odds of spontaneous preterm birth in the first month of lockdown from an interrupted time series model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each country provided in Table 1. *Restricted to births from 24 weeks onwards in New South Wales, Australia and Wales, and from 28 weeks onwards in Scotland; **Live births only*



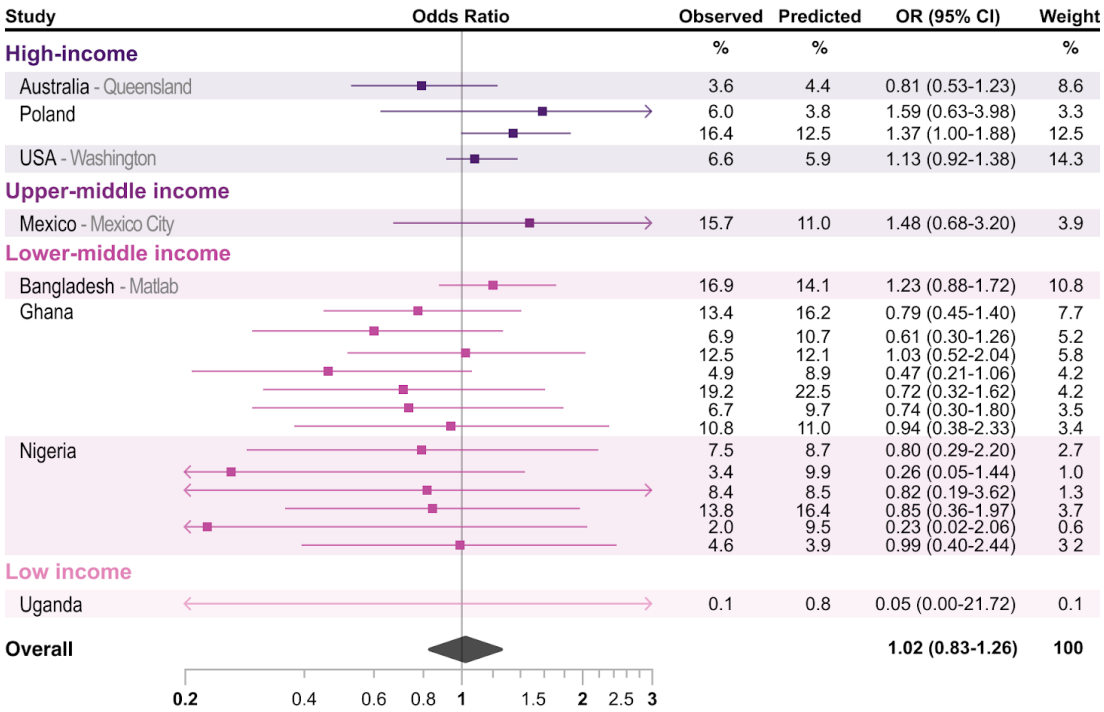
*Supplementary Figure 30: Individual and pooled **population-based estimates** of the association between lockdown and the odds of **spontaneous preterm birth** among all births 22 weeks onwards, in the **second month** of lockdown. Individual country odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of spontaneous preterm birth in the second month of lockdown to the forecasted odds of spontaneous preterm birth in the second month of lockdown from an interrupted time series model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each country provided in Table 1. *Restricted to births from 24 weeks onwards in New South Wales, Australia and Wales, and from 28 weeks onwards in Scotland; **Live births only*



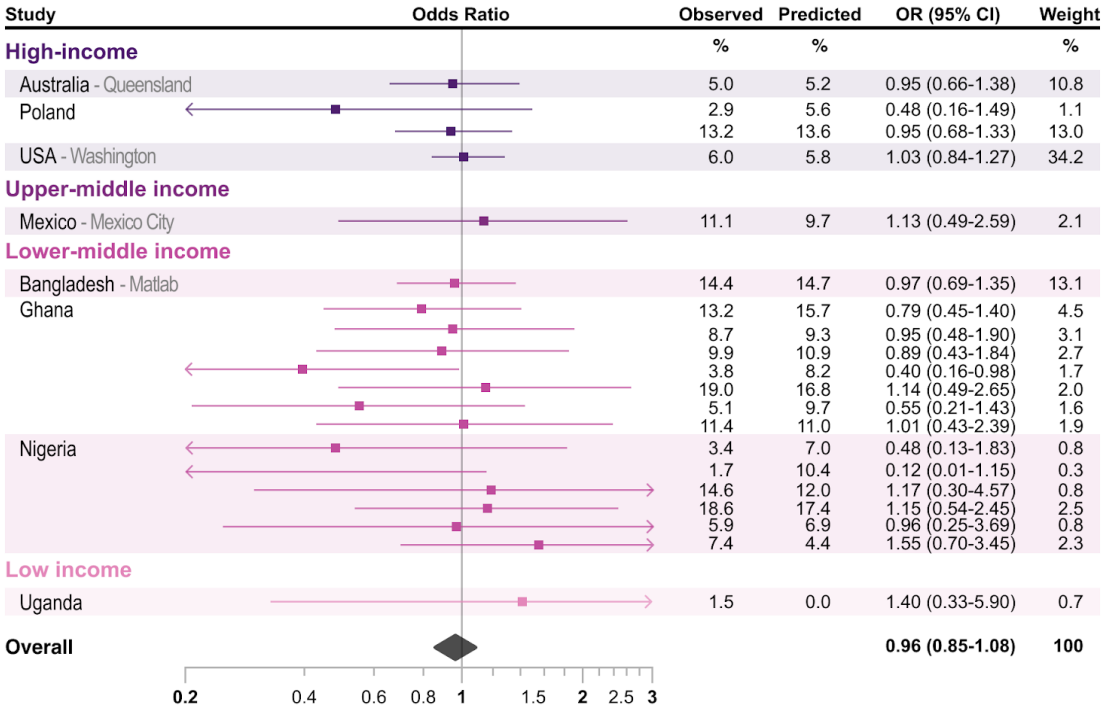
*Supplementary Figure 31: Individual and pooled **population-based estimates** of the association between lockdown and the odds of **spontaneous preterm birth** among all births 22 weeks onwards, in the **third month** of lockdown. Individual country odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of spontaneous preterm birth in the third month of lockdown to the forecasted odds of spontaneous preterm birth in the third month of lockdown from an interrupted time series model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each country provided in Table 1. *Restricted to births from 24 weeks onwards in New South Wales, Australia and Wales, and from 28 weeks onwards in Scotland; **Live births only*



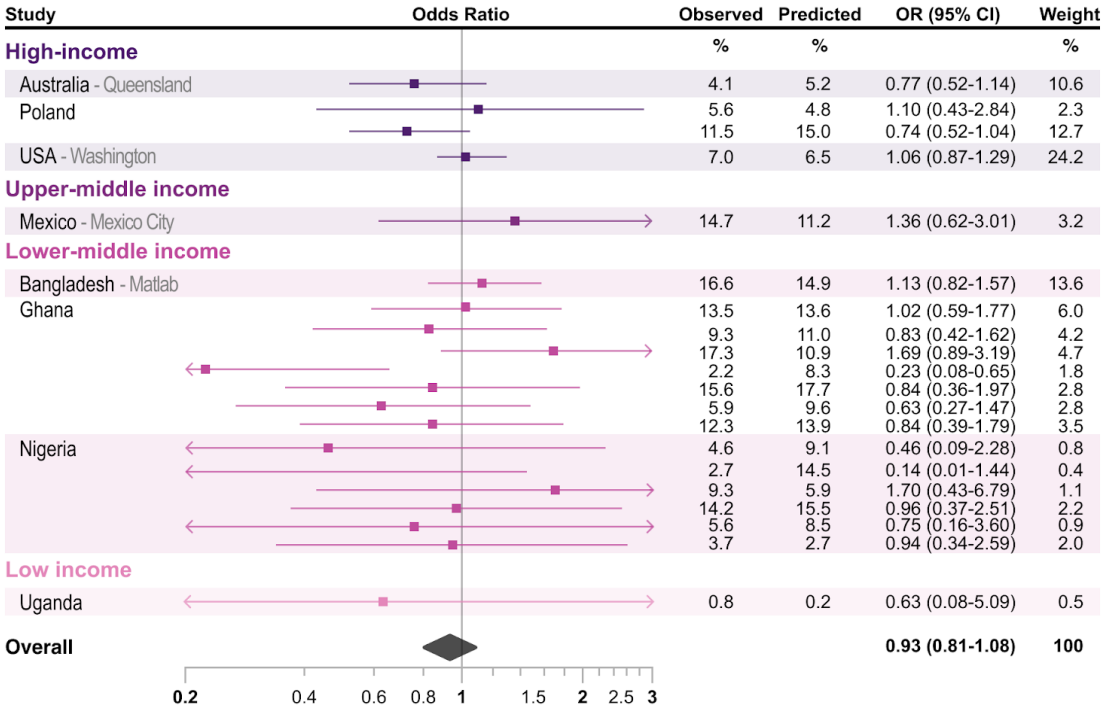
*Supplementary Figure 32: Individual and pooled **population-based estimates** of the association between lockdown and the odds of **spontaneous preterm birth** among all births 22 weeks onwards, in the **fourth month** of lockdown. Individual country odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of spontaneous preterm birth in the fourth month of lockdown to the forecasted odds of spontaneous preterm birth in the fourth month of lockdown from an interrupted time series model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each country provided in Table 1. *Restricted to births from 24 weeks onwards in New South Wales, Australia and Wales, and from 28 weeks onwards in Scotland; **Live births only*



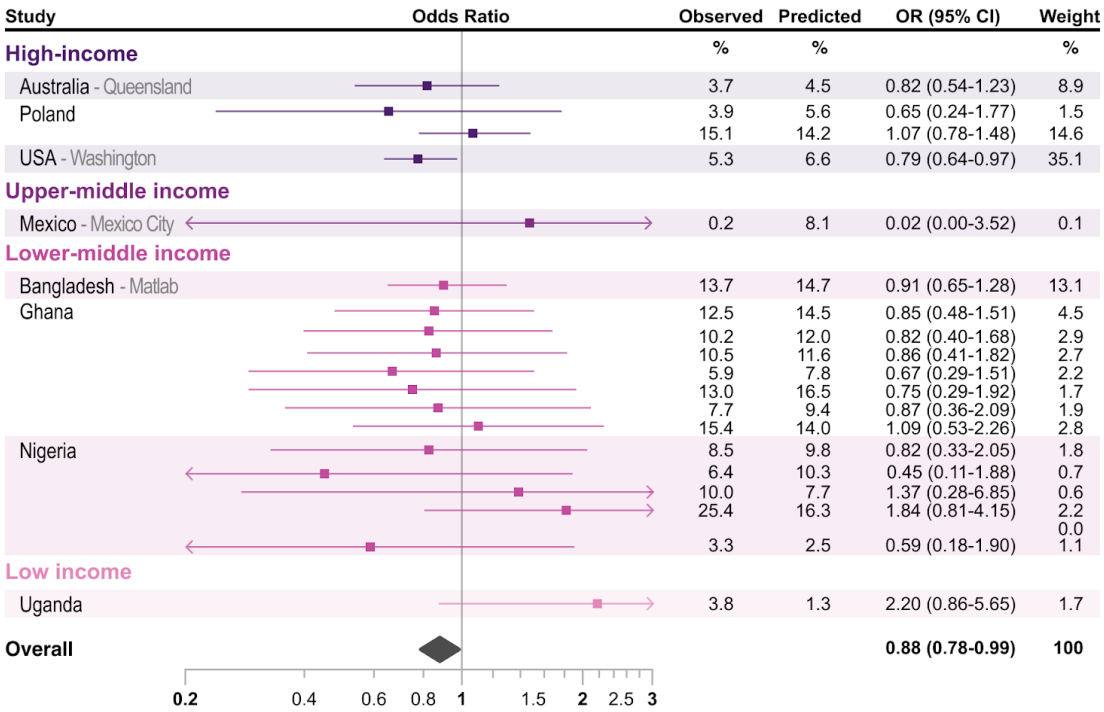
*Supplementary Figure 33: Individual and pooled **non-population-based estimates** of the association between lockdown and the odds of **spontaneous preterm birth** among all births 22 weeks onwards, in the **first month** of lockdown. Individual dataset odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of spontaneous preterm birth in the first month of lockdown to the forecasted odds of spontaneous preterm birth in the first month of lockdown from a linear regression model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each dataset provided in Table 2.*



*Supplementary Figure 34: Individual and pooled **non-population-based estimates** of the association between lockdown and the odds of **spontaneous preterm birth** among all births 22 weeks onwards, in the **second month** of lockdown. Individual dataset odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of spontaneous preterm birth in the second month of lockdown to the forecasted odds of spontaneous preterm birth in the second month of lockdown from a linear regression model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each dataset provided in Table 2.*

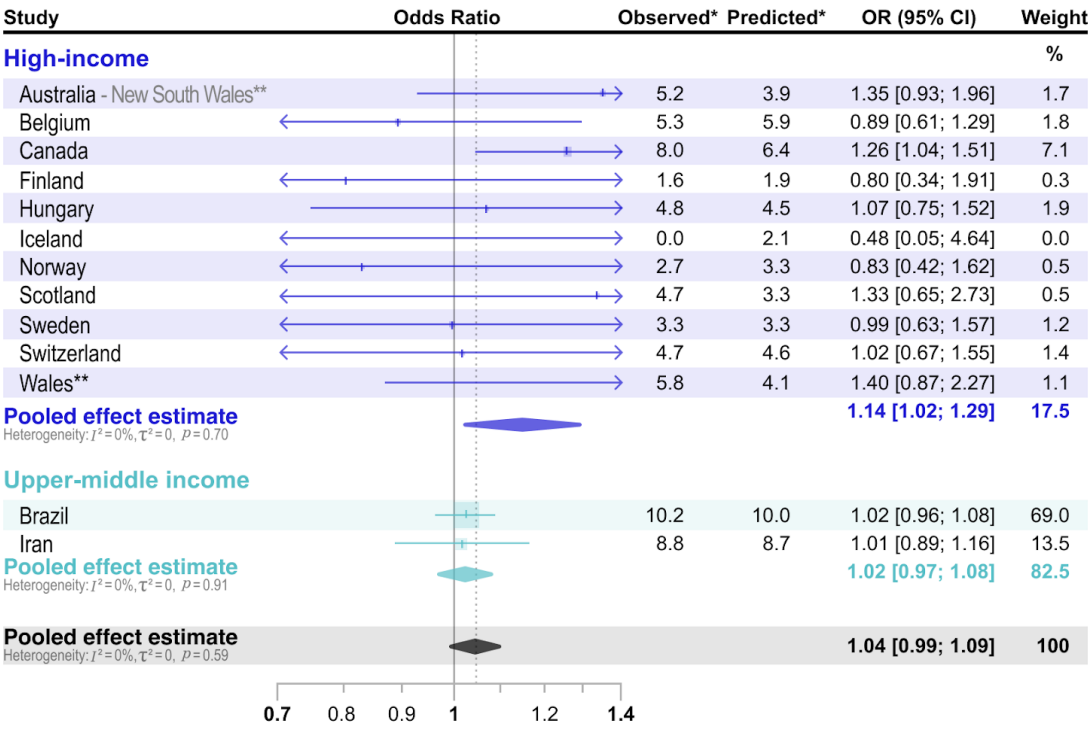


*Supplementary Figure 35: Individual and pooled **non-population-based estimates** of the association between lockdown and the odds of **spontaneous preterm birth** among all births 22 weeks onwards, in the **third month** of lockdown. Individual dataset odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of spontaneous preterm birth in the third month of lockdown to the forecasted odds of spontaneous preterm birth in the third month of lockdown from a linear regression model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each dataset provided in Table 2.*

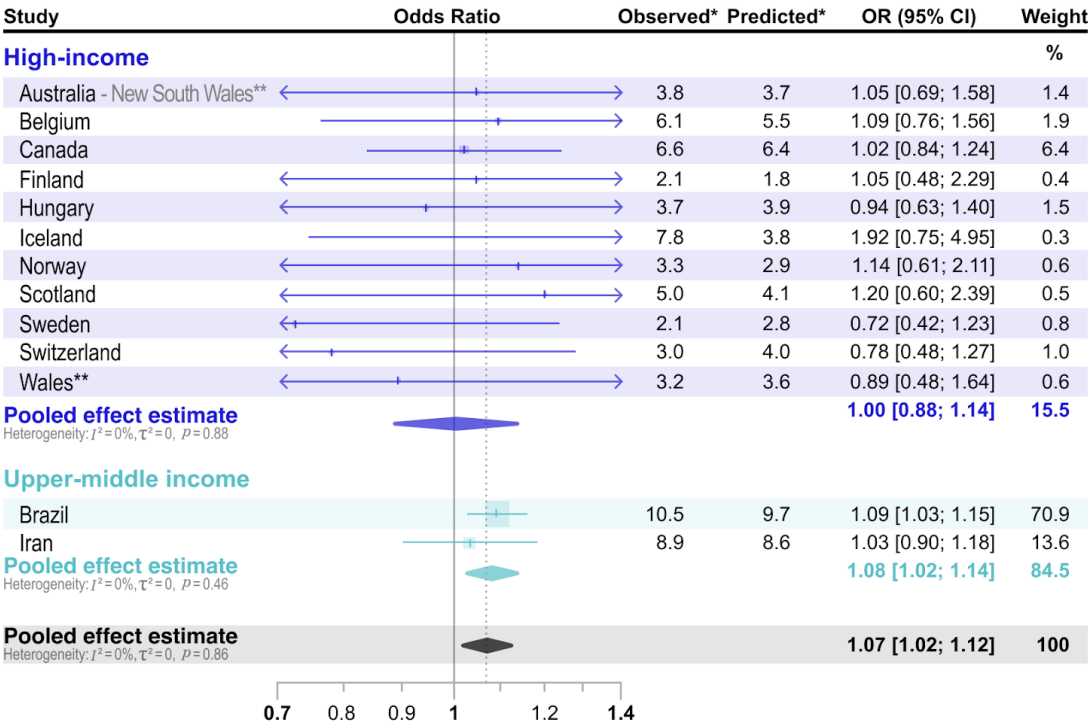


*Supplementary Figure 36: Individual and pooled **non-population-based estimates** of the association between lockdown and the odds of **spontaneous preterm birth** among all births 22 weeks onwards, in the **fourth month** of lockdown. Individual dataset odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of spontaneous preterm birth in the fourth month of lockdown to the forecasted odds of spontaneous preterm birth in the fourth month of lockdown from a linear regression model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each dataset provided in Table 2.*

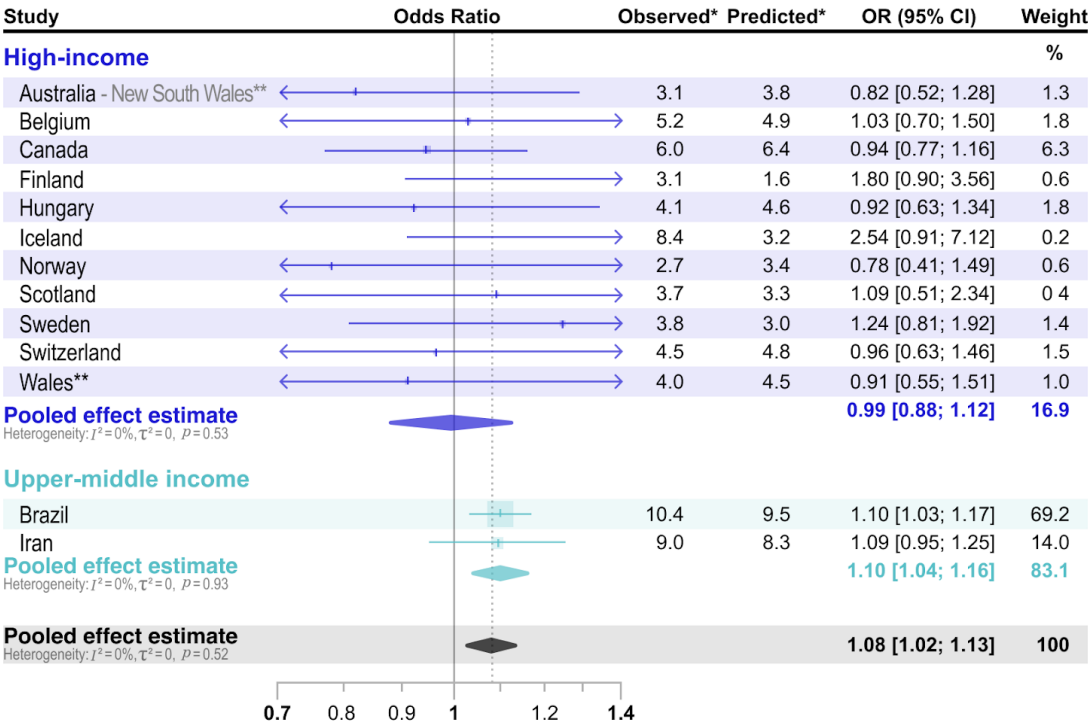
Association between lockdown and stillbirth rates, by time since lockdown



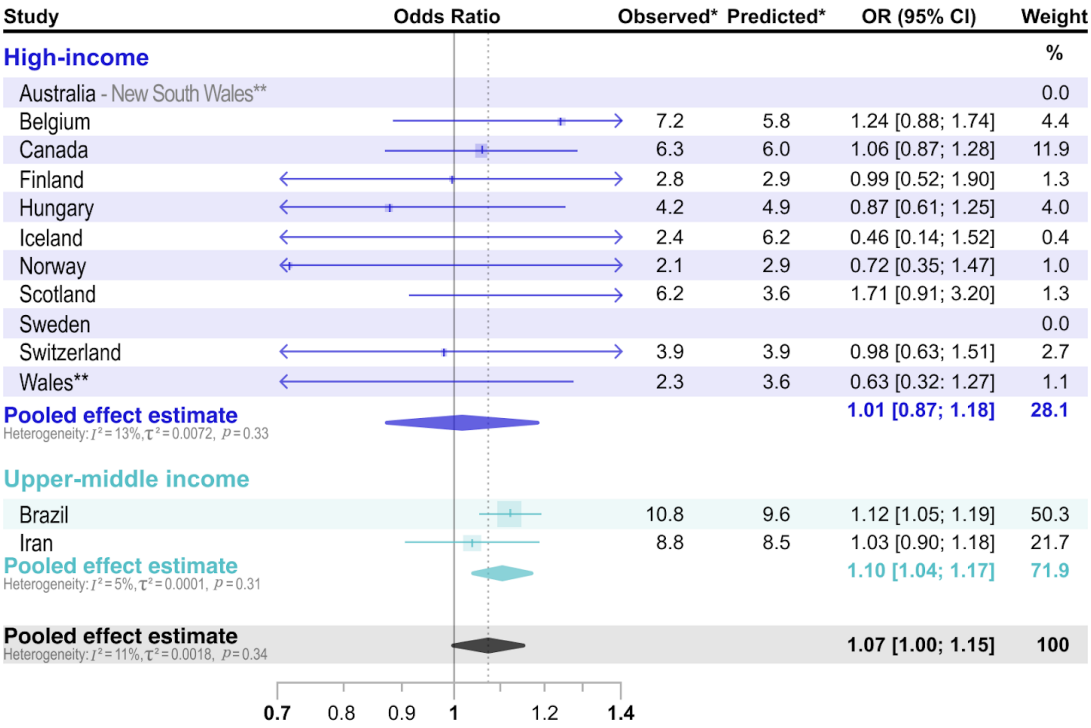
*Supplementary Figure 37: Individual and pooled **population-based estimates** of the association between lockdown and the odds of **stillbirth** among all births 22 weeks onwards, in the **first month** of lockdown. Individual country odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of stillbirth in the first month of lockdown to the forecasted odds of stillbirth in the first month of lockdown from an interrupted time series model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each country provided in Table 1. *Per 1000 births;**Restricted to births to births from 24 weeks onwards*



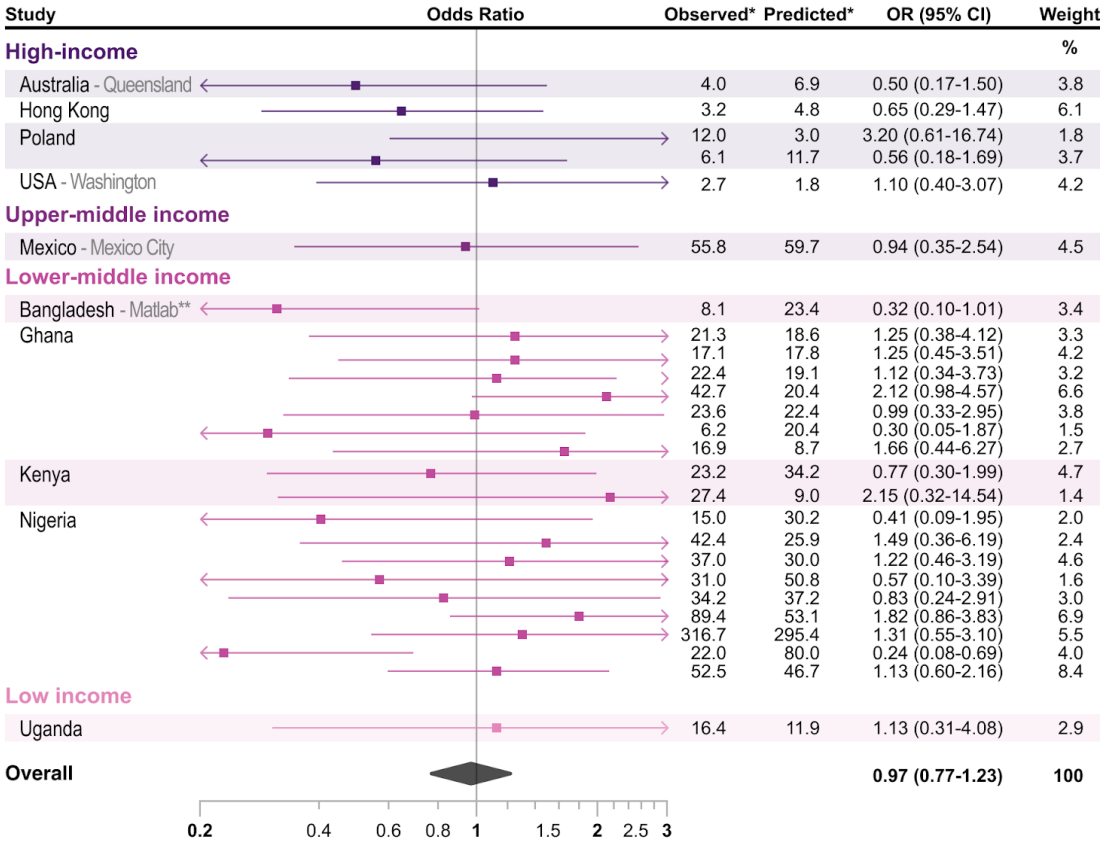
*Supplementary Figure 38: Individual and pooled **population-based estimates** of the association between lockdown and the odds of **stillbirth** among all births 22 weeks onwards, in the **second month** of lockdown. Individual country odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of stillbirth in the second month of lockdown to the forecasted odds of stillbirth in the second month of lockdown from an interrupted time series model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each country provided in Table 1. *Per 1000 births;**Restricted to births to births from 24 weeks onwards*



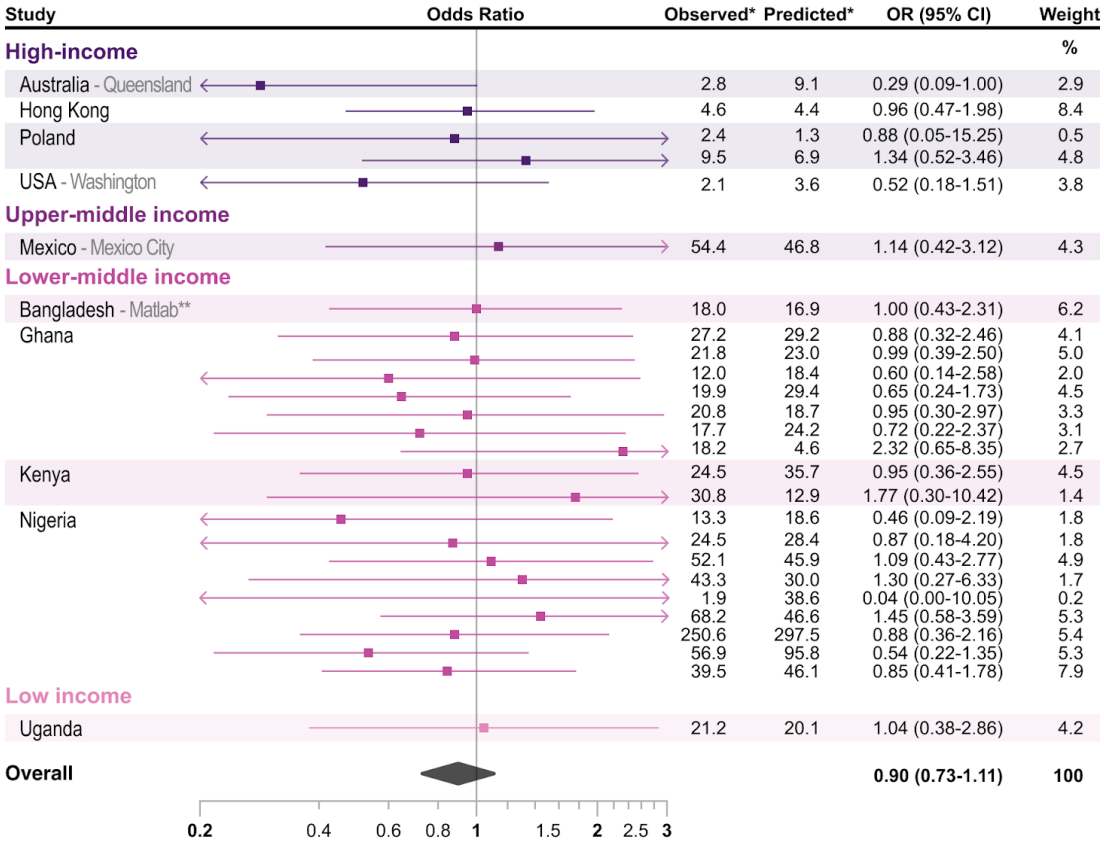
*Supplementary Figure 39: Individual and pooled **population-based estimates** of the association between lockdown and the odds of **stillbirth** among all births 22 weeks onwards, in the **third month** of lockdown. Individual country odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of stillbirth in the third month of lockdown to the forecasted odds of stillbirth in the third month of lockdown from an interrupted time series model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each country provided in Table 1. *Per 1000 births;**Restricted to births to births from 24 weeks onwards*



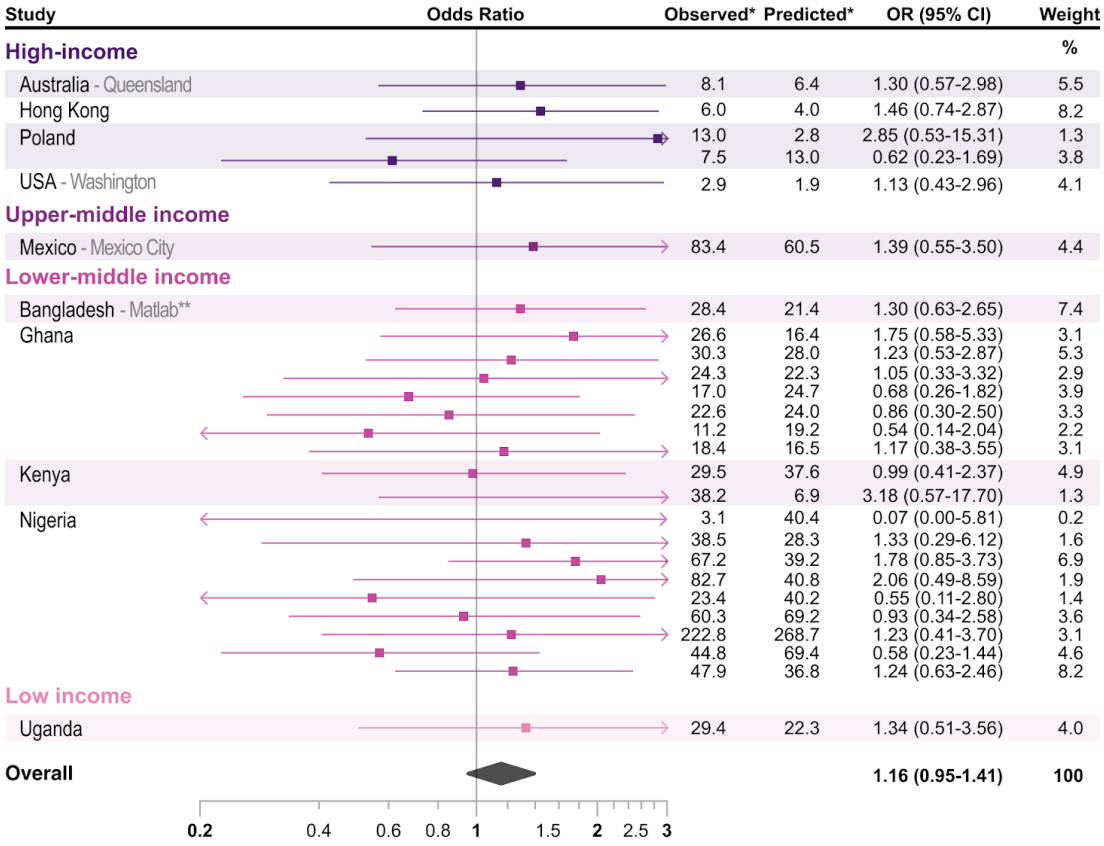
*Supplementary Figure 40: Individual and pooled **population-based estimates** of the association between lockdown and the odds of **stillbirth** among all births 22 weeks onwards, in the **fourth month** of lockdown. Individual country odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of stillbirth in the fourth month of lockdown to the forecasted odds of stillbirth in the fourth month of lockdown from an interrupted time series model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each country provided in Table 1. *Per 1000 births;**Restricted to births to births from 24 weeks onwards*



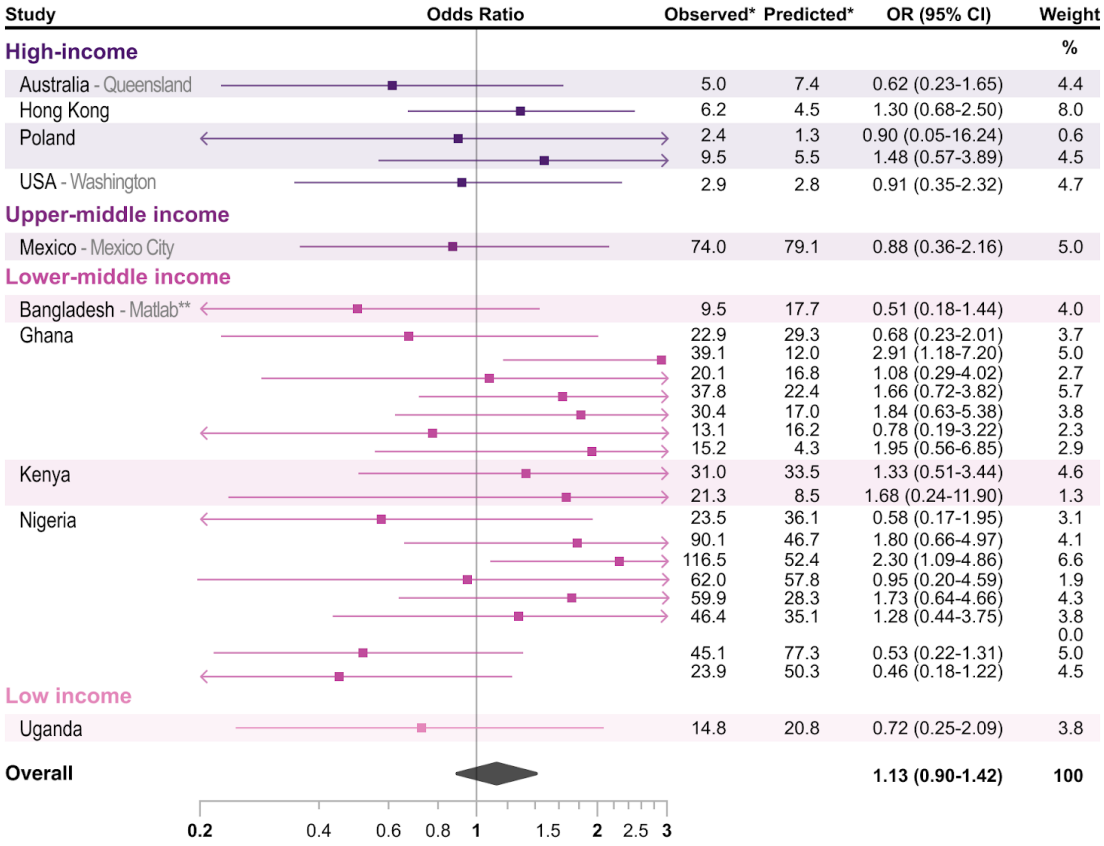
*Supplementary Figure 41: Individual and pooled **non-population-based estimates** of the association between lockdown and the odds of **stillbirth** among all births 22 weeks onwards, in the **first month** of lockdown. Individual dataset odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of stillbirth in the first month of lockdown to the forecasted odds of stillbirth in the first month of lockdown from a linear regression model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each dataset provided in Table 2. *Per 1000 births;**Restricted to births from 28 weeks onwards*



*Supplementary Figure 42: Individual and pooled **non-population-based estimates** of the association between lockdown and the odds of **stillbirth** among all births 22 weeks onwards, in the **second month** of lockdown. Individual dataset odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of stillbirth in the second month of lockdown to the forecasted odds of stillbirth in the second month of lockdown from a linear regression model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each dataset provided in Table 2. *Per 1000 births;**Restricted to births from 28 weeks onwards*



*Supplementary Figure 43: Individual and pooled **non-population-based estimates** of the association between lockdown and the odds of **stillbirth** among all births 22 weeks onwards, in the **third month** of lockdown. Individual dataset odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of stillbirth in the third month of lockdown to the forecasted odds of stillbirth in the third month of lockdown from a linear regression model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each dataset provided in Table 2. *Per 1000 births;**Restricted to births from 28 weeks onwards*



*Supplementary Figure 44: Individual and pooled **non-population-based estimates** of the association between lockdown and the odds of **stillbirth** among all births 22 weeks onwards, in the **fourth month** of lockdown. Individual dataset odds ratios (represented by boxes on plot) were calculated by comparing the observed odds of stillbirth in the fourth month of lockdown to the forecasted odds of stillbirth in the fourth month of lockdown from a linear regression model that was fitted to pre-lockdown data. Horizontal lines surrounding each box on the forest plot are 95% confidence intervals. Arrows indicate upper and or lower bounds of the confidence interval that are outside the x-axis limits. Sample sizes for each dataset provided in Table 2. *Per 1000 births;**Restricted to births from 28 weeks onwards*

Supplementary Tables

Supplementary Table 1: Summary of datasets included in the international Perinatal Outcomes in the Pandemic (iPOP) Study.

World Region Country (Region)	World Bank Income Setting	Data source	Nationwide, regional data, hospital or other data (% of births covered for population-based datasets)	Method/s used in data source to estimate gestational age	Years	Date of first COVID-19 lockdown in 2020 (i.e., Oxford Stringency Index reached 50 or over)*	Oxford Stringency Index at lockdown (max in first lockdown period)*
Population-based							
Asia-Pacific							
Australia (New South Wales)	High	Perinatal Data Collection (PDC) including all live- and stillbirths	Regional, Statewide (>99%)	Ultrasound, last menstrual period	2015-2020	March 23	52.8 (75.5)
Middle East & North Africa							
Iran	Upper-middle	National neonatal data including all live- and stillbirths	National (>95%)	Ultrasound, last menstrual period	2017-2020	March 19	51.9 (59.3)
Europe							
Belgium	High	Regional Birth Register including all live- and stillbirths	National (100%)	Ultrasound, last menstrual period	2015-2020	March 14	50.9 (81.5)
Denmark	High	Regional Birth Register including all live- and stillbirths	Regional (98% of births in Central Denmark Region)	Ultrasound, last menstrual period	2016-2020	March 13	63.0 (72.2)

Finland	High	National Medical Birth Register including all live- and stillbirths	National (100%)	Ultrasound, last menstrual period	2015-2020	March 16	61.1 (71.3)
Hungary	High	National Birth Register including all live- and stillbirths	National (100%)	Last menstrual period	2015-2020	March 12	50.0 (76.9)
Iceland	High	National Medical Birth Register including all live- and stillbirths	National (100%)	Ultrasound, last menstrual period	2015-2020	March 16	50.9 (53.7)
Norway	High	National Medical Birth Register including all live- and stillbirths	National (100%)	Ultrasound, last menstrual period	2015-2020	March 15	51.8 (79.6)
Scotland	High	Maternity care discharge records linked to statutory stillbirth records including all live- and stillbirths, but excluding home births	National (99%)	Ultrasound, last menstrual period	2015-2020	March 22	62.0 (79.6)
Sweden	High	Swedish Pregnancy Register including all live- and stillbirths, but excluding planned births outside of hospital, excluding planned home births but including unplanned births outside of hospital	National (94%)	Ultrasound, last menstrual period	2015-2020	March 25	50.9 (64.8)
Switzerland	High	Federal Statistical Office, Vital Statistics (BEVNAT) Switzerland including live- and stillbirths	National (100%)	Ultrasound, last menstrual period, symphysis-fundal height	2015-2020	March 17	73.2 (73.2)
Wales	High	National Community Child Health Database and Maternity Indicators Dataset including all live- and stillbirths	National (100%)	Ultrasound, last menstrual period	2015-2020	March 22	62.0 (79.6)
North America							

Canada (excluding Quebec)	High	Canadian Institute for Health Information (CIHI) Discharge Abstract Database (DAD), including live- and stillbirths, but excluding home births	National (98%)	Ultrasound, last menstrual period	2015-2020	March 18	61.1 (74.5)
USA	High	Data extracted from birth certificates, which are required to be completed for all births	National (>99%)	Ultrasound, last menstrual period	2015-2020	March 16	52.3 (72.7)
Latin America & Caribbean							
Brazil	Upper-middle	National Birth Register including all live- and stillbirths	National (100%)	Last menstrual period	2015-2020	March 17	57.9 (81.0)
Chile	High	National Birth Registry including all live births	National (100%)	Ultrasound, last menstrual period	2015-2020	March 18	55.6 (87.5)
Peru	Upper-middle	National Birth Registry including all live births	National (100%)	Ultrasound, last menstrual period, ballard score, other	2016-2020	March 14	50.0 (96.3)
Uruguay	High	National birth register including live- and stillbirths	National (>99%)	Last menstrual period, ballard score	2015-2020	March 15	51.9 (72.2)
Non-population-based							
Asia-Pacific							
Australia (Queensland)	High	Antenatal data record from a tertiary facility including live- and stillbirths, including home births	One hospital	Ultrasound, last menstrual period	2015-2020	March 23	52.8 (75.5)
Hong Kong	High	Clinical Data Analysis and Reporting System (CDARS) including all live- and stillbirths from all public	Facility (80% of all births in Hong Kong, excludes private sector)	Ultrasound, last menstrual period	2015-2020	February 8	52.8 (66.7)

		sector health facilities					
South Asia							
Bangladesh	Lower-middle	Data from Matlab Health and Demographic Surveillance System (HDSS) including live- and stillbirths at both home and in facilities	Demographic surveillance system (coverage 90% of study area)	Ultrasound, last menstrual period	2015-2020	March 19	75.9 (93.5)
Europe							
Poland	High	Hospital medical records including live- and stillbirths	Two hospitals	Ultrasound, last menstrual period	2015-2020	March 15	57.4 (87.0)
North America							
USA (Washington State)	High	Obstetrical Care Outcomes Assessment Program, maternal and neonatal medical records	14 hospitals	Ultrasound, last menstrual period	2017-2020	March 16	52.3 (72.7)
Latin America & Caribbean							
Mexico	Upper-middle	Medical records from tertiary facility, hospital maternity and labour ward records including live- and stillbirths	One hospital	Ultrasound, last menstrual period	2017-2020	March 24	52.8 (82.4)
Sub-Saharan Africa							
Ghana	Lower-middle	Paper-based births registers including live- and stillbirths	Seven hospitals	Ultrasound, last menstrual period, symphysis-fundal height	1 hospital: 2015-2020 6 hospitals: 2017-2020	March 18	50.0 (86.1)
Kenya	Lower-middle	Hospital birth registry including live- and stillbirths	Two hospitals	Ultrasound, last menstrual period	2015-2020	March 15	50.9 (88.9)
Nigeria	Lower-middle	Hospital birth registry including live- and stillbirths	Four hospitals	Ultrasound, last menstrual	2015-2020	March 26	52.3 (85.6)

				period, symphysis-fundal height			
		Hospital birth registry including live- and stillbirths	Three hospitals	Last menstrual period, Ultrasound dating	2015-2020		
		Hospital birth registry including live- and stillbirths	Two hospitals	Last menstrual period, Ultrasound dating	2015-2020		
Uganda	Low	Hospital birth registry including live- and stillbirths	One hospital	Ultrasound, last menstrual period, ballard score	2015-2020	March 25	69.4 (93.5)

*From Oxford COVID-19 Government Response Tracker: https://www.bsg.ox.ac.uk/research/research-projects/covid-19-government-response-tracker

Supplementary Table 2: Datasets excluded from the study analysis and reasons why

Country	Dataset and type	Reason for exclusion
Nepal	All, seven facilities	Data started from January 2018, and in most facilities there was a data quality exercise conducted in early 2019 inflating preterm birth rates during this period, making it impossible to draw inferences about impact of lockdown in 2020 (see Supplementary Figure 1).
Ghana	Facility 1	Small numbers of births (<50 per month).
	Facility 8 & 10	No available data for 2015-2019, only 2020.
Nigeria	Facility 5 & 6	No available data on gestational age, only birth weight. These are peripheral facilities which generally do not collect data on gestational age.
	Facility 7	While this is the largest private facility conducting private deliveries in the state, there were relatively small number of births (<50 per month).
Kenya	Facility 2	No data available from April 2020 onwards.
Uganda	Facility 1	Seven months of data missing in 2019.

Sensitivity analysis: comparison of change in association between lockdown and preterm births rates when using all births versus live births only

Supplementary Table 3: Odds ratio for change in preterm birth rates (births from 22 weeks onwards) with lockdown calculated by using [1] all births and [2] live births only for all population-based datasets

Country	First month of lockdown	Second month of lockdown	Third month of lockdown	Fourth month of lockdown
Australia, NSW*				
All births	0.92 (0.83-1.03)	1.02 (0.91-1.13)	0.97 (0.87-1.08)	-
Live births	0.90 (0.81-1.01)	1.01 (0.91-1.13)	0.97 (0.87-1.08)	-
Belgium				
All births	0.88 (0.79-0.98)	0.93 (0.83-1.04)	0.96 (0.86-1.07)	1.06 (0.96-1.17)
Live births	0.89 (0.79-0.99)	0.93 (0.83-1.03)	0.97 (0.87-1.08)	1.06 (0.95-1.17)
Brazil				
All births	1.00 (0.96-1.04)	1.04 (0.99-1.08)	1.04 (0.99-1.08)	1.03 (0.99-1.08)
Live births	1.00 (0.95-1.04)	1.03 (0.99-1.08)	1.03 (0.99-1.08)	1.03 (0.98-1.07)
Canada				
All births	0.95 (0.89-1.02)	0.98 (0.92-1.05)	0.95 (0.89-1.02)	1.02 (0.96-1.08)
Live births	0.97 (0.91-1.04)	1.01 (0.95-1.08)	0.97 (0.91-1.04)	1.04 (0.98-1.11)
Denmark, Central Region				
All births	1.01 (0.74-1.37)	1.03 (0.77-1.40)	1.16 (0.87-1.55)	0.89 (0.66-1.20)
Live births	1.01 (0.74-1.37)	1.04 (0.77-1.40)	1.16 (0.87-1.54)	0.89 (0.67-1.20)
Finland				
All births	1.06 (0.89-1.26)	1.04 (0.87-1.23)	1.07 (0.90-1.28)	1.02 (0.86-1.21)
Live births	1.06 (0.89-1.27)	1.03 (0.90-1.18)	1.06 (0.89-1.26)	1.01 (0.85-1.20)
Hungary				
All births	1.00 (0.87-1.14)	1.02 (0.90-1.17)	0.98 (0.87-1.12)	1.01 (0.90-1.14)
Live births	0.99 (0.86-1.13)	1.03 (0.90-1.18)	0.99 (0.86-1.13)	1.03 (0.90-1.16)
Iceland				
All births	1.24 (0.71-2.16)	0.75 (0.41-1.35)	0.71 (0.39-1.30)	0.88 (0.49-1.59)
Live births	1.25 (0.72-2.19)	0.66 (0.35-1.25)	0.62 (0.32-1.18)	0.89 (0.49-1.63)
Iran				
All births	0.87 (0.78-0.98)	0.92 (0.82-1.03)	0.97 (0.87-1.09)	1.00 (0.90-1.12)
Live births	0.86 (0.76-0.97)	0.91 (0.81-1.02)	0.96 (0.86-1.08)	1.00 (0.90-1.11)
Norway				
All births	1.01 (0.88-1.16)	0.99 (0.86-1.15)	0.84 (0.72-0.97)	0.97 (0.84-1.12)
Live births	1.02 (0.89-1.18)	0.99 (0.85-1.15)	0.83 (0.71-0.97)	0.98 (0.85-1.14)
Scotland				
All births	0.91 (0.79-1.05)	0.86 (0.75-1.00)	1.05 (0.92-1.20)	0.96 (0.83-1.10)
Live births	0.89 (0.77-1.03)	0.85 (0.74-0.99)	1.05 (0.91-1.20)	0.95 (0.82-1.09)
Sweden				
All births	1.01 (0.90-1.13)	0.94 (0.84-1.05)	0.98 (0.87-1.10)	-
Live births	1.01 (0.90-1.13)	0.95 (0.85-1.07)	0.97 (0.86-1.09)	-
Switzerland				
All births	0.98 (0.86-1.10)	0.90 (0.80-1.02)	1.04 (0.93-1.17)	1.08 (0.96-1.22)
Live births	0.97 (0.86-1.08)	0.90 (0.80-1.01)	1.05 (0.94-1.17)	1.09 (0.97-1.22)
Uruguay				
All births	0.95 (0.80-1.13)	1.00 (0.84-1.19)	1.03 (0.87-1.23)	0.90 (0.76-1.08)

Live births	0.98 (0.82-1.12)	1.04 (0.87-1.24)	1.06 (0.88-1.26)	0.94 (0.78-1.12)
Wales*				
All births	0.95 (0.81-1.11)	0.89 (0.75-1.05)	0.96 (0.83-1.12)	1.03 (0.88-1.20)
Live births	0.96 (0.82-1.12)	0.89 (0.75-1.05)	0.96 (0.83-1.12)	1.04 (0.89-1.22)

*Births 24 weeks onwards; NSW=New South Wales

Sensitivity analysis: comparison of change in association between lockdown and preterm births rates when restricting to births 28 weeks onwards

Supplementary Table 4: Odds ratio for change in preterm birth rates with lockdown calculated by using [1] all births 22 weeks onwards and [2] all births from 28 weeks onwards, for all population-based datasets

Country	First month of lockdown	Second month of lockdown	Third month of lockdown	Fourth month of lockdown
Belgium				
22 weeks	0.88 (0.79-0.98)	0.93 (0.83-1.04)	0.96 (0.86-1.07)	1.06 (0.96-1.17)
28 weeks	0.90 (0.81-0.99)	0.95 (0.86-1.05)	0.96 (0.87-1.06)	1.06 (0.96-1.16)
Brazil				
22 weeks	1.00 (0.96-1.04)	1.04 (0.99-1.08)	1.04 (0.99-1.08)	1.03 (0.99-1.08)
28 weeks	1.00 (0.96-1.05)	1.04 (0.99-1.08)	1.04 (1.00-1.09)	1.03 (0.98-1.08)
Canada				
22 weeks	0.95 (0.89-1.02)	0.98 (0.92-1.05)	0.95 (0.89-1.02)	1.02 (0.96-1.08)
28 weeks	0.95 (0.95-1.02)	0.99 (0.93-1.06)	0.97 (0.91-1.03)	1.02 (0.96-1.08)
Denmark, Central Region				
22 weeks	1.01 (0.74-1.37)	1.03 (0.77-1.40)	1.16 (0.87-1.55)	0.89 (0.66-1.20)
28 weeks	1.01 (0.73-1.40)	1.02 (0.75-1.40)	1.04 (0.76-1.41)	0.81 (0.59-1.11)
Finland				
22 weeks	1.06 (0.89-1.26)	1.04 (0.87-1.23)	1.07 (0.90-1.28)	1.02 (0.86-1.21)
28 weeks	1.05 (0.88-1.26)	1.01 (0.85-1.20)	1.05 (0.88-1.26)	1.00 (0.84-1.18)
Hungary				
22 weeks	1.00 (0.87-1.14)	1.02 (0.90-1.17)	0.98 (0.87-1.12)	1.01 (0.90-1.14)
28 weeks	1.00 (0.87-1.14)	1.01 (0.88-1.15)	0.99 (0.87-1.13)	1.01 (0.89-1.14)
Iceland				
22 weeks	1.24 (0.71-2.16)	0.75 (0.41-1.35)	0.71 (0.39-1.30)	0.88 (0.49-1.59)
28 weeks	1.16 (0.64-2.08)	0.67 (0.35-1.27)	0.67 (0.35-1.28)	0.85 (0.45-1.58)
Iran				
22 weeks	0.87 (0.78-0.98)	0.92 (0.82-1.03)	0.97 (0.87-1.09)	1.00 (0.90-1.12)
28 weeks	0.87 (0.77-0.98)	0.91 (0.82-1.02)	0.97 (0.86-1.08)	1.01 (0.91-1.12)
Norway				
22 weeks	1.01 (0.88-1.16)	0.99 (0.86-1.15)	0.84 (0.72-0.97)	0.97 (0.84-1.12)
28 weeks	1.01 (0.87-1.18)	0.99 (0.85-1.16)	0.84 (0.72-0.99)	0.95 (0.81-1.11)
Scotland				
22 weeks	0.91 (0.79-1.05)	0.86 (0.75-1.00)	1.05 (0.92-1.20)	0.96 (0.83-1.10)
28 weeks	0.91 (0.79-1.05)	0.85 (0.73-0.98)	1.05 (0.91-1.20)	0.96 (0.83-1.10)
Sweden				
22 weeks	1.01 (0.90-1.13)	0.94 (0.84-1.05)	0.98 (0.87-1.10)	-
28 weeks	1.03 (0.92-1.15)	0.93 (0.83-1.04)	0.97 (0.87-1.09)	-
Switzerland				
22 weeks	0.98 (0.86-1.10)	0.90 (0.80-1.02)	1.04 (0.93-1.17)	1.08 (0.96-1.22)
28 weeks	0.99 (0.87-1.12)	0.90 (0.79-1.02)	1.04 (0.92-1.17)	1.09 (0.97-1.23)
Uruguay				
22 weeks	0.95 (0.80-1.13)	1.00 (0.84-1.19)	1.03 (0.87-1.23)	0.90 (0.76-1.08)
28 weeks	0.95 (0.79-1.14)	0.99 (0.82-1.19)	1.05 (0.88-1.26)	0.90 (0.75-1.09)
Wales*				
24 weeks	0.95 (0.81-1.11)	0.89 (0.75-1.05)	0.96 (0.83-1.12)	1.03 (0.88-1.20)
28 weeks	0.93 (0.78-1.10)	0.88 (0.73-1.05)	0.98 (0.83-1.15)	1.01 (0.85-1.20)

*Births 24 weeks onwards

Sensitivity analysis: comparison of change in association between lockdown and preterm births rates in the meta-analysis when removing large countries

Supplementary Table 5: Pooled population-based estimates of the association between lockdown and the odds of preterm birth among all births 22 weeks onwards by month of lockdown, with estimates presented for our primary analysis (including all population-based datasets) as well as the sensitivity analysis excluding data from Brazil and the USA

Month of lockdown	Primary analysis (including all countries)		Sensitivity analysis (excluding data from Brazil and the USA)	
	Number of studies	Pooled odds ratio (95% CI)	Number of studies	Pooled odds ratio (95% CI)
First month	18	0.96 (0.95-0.98)	16	0.96 (0.93-0.98)
Second month	18	0.96 (0.92-0.99)	16	0.95 (0.91-0.99)
Third month	18	0.97 (0.94-1.00)	16	0.96 (0.93-1.00)
Fourth month	16	0.99 (0.96-1.01)	14	0.98 (0.95-1.02)

*CI=Confidence interval

Supplementary Table 6: Details of ethical approval

Country, Region/Site	Ethical Approval Required	Further details
Population-based data		
Asia-Pacific		
Australia, New South Wales	Yes	Use of aggregated data for this study was approved by the NSW Population and Health Services Research Ethics Committee (2019/ETH11532)
Middle East & North Africa		
Iran	Yes	National approval code: IR.MUI.REC.1400.043.
Europe		
Belgium	Yes	The Ethics committee of the hospital AZ St-Jan Bruges was informed and responded to us on 16/02/2021 the following: *"The Ethics committee has received the documentation of the aforementioned trial. We have no objections for this retrospective non-interventional study to be performed".*
Denmark, Central Region	Yes	Permission to data access was obtained from the Regional Council of the Central Denmark Region (§46 permission), sagnr. 1-45-70-43-20, 6 Jan 2021.Data protection (GDPR) sagsnr 1-16-02-611-20 and permission to share anonymised data was obtained 26 Jan 2021.
Finland	No	Only aggregated data provided, no need for ethical approval
Hungary	No	Only aggregated data provided, no need for ethical approval
Iceland	Yes	Ethical approval was obtained from the National Bioethics Committee on Oct 13th, 2020. VSNb2020080003/03.0 I
Norway	No	Only aggregated data provided, no need for ethical approval
Scotland	Yes	Ethical approval per se was not required, but approval for contribution of Scottish data was secured from the Public Health Scotland Data Protection team
Sweden	No	Only aggregated data provided, no need for ethical approval
Switzerland	No	Only aggregated data provided, no need for ethical approval
Wales	No	Data provided through SAIL.
North America		
Canada	No	Only aggregated data provided from publicly available data, no need for ethical approval
USA	No	Only aggregated data provided from publicly available data, no need for ethical approval
Latin America & Caribbean		
Brazil	No	Only aggregated data provided from publicly available data, no need for ethical approval
Chile	No	No ethical approval needed given that public access databases of the Civil Registry Service (for 2019 and 2020) and the Department of Statistics of the Ministry of Health were accessed from 2015 to 2018
Peru	No	Only aggregated data provided, no need for ethical approval. However, the study protocol was approved by the Institutional Review Board of Universidad Peruana Cayetano Heredia (Reference Number: CONSTANCIA 101-01-21)
Uruguay	No	Only aggregated data provided from publicly available data, no need for ethical approval
Non-population-based data		
Asia-Pacific		
Hong Kong	Yes	The study protocol was approved by the Institutional Review Board of the University of Hong Kong/ Hospital Authority Hong Kong West Cluster for CDARS database research (Reference Number: UW 20-166)
Australia, Queensland	No	Did not meet requirements for HREC review and is considered a clinical audit. EXMT/MML/73974 (V1)
South Asia		
Matlab, Bangladesh	Yes	Ethical approval was received by the IRB of International Centre for diarrheal Disease Research, Bangladesh (icddr,b)

Europe		
Poland		
Poznań University of Medical Sciences	No	Only aggregated data provided, no need for ethical approval. Waiver was obtained from the Poznań University of Medical Sciences Ethical Review Board.
Poznań Regional Hospital	No	Only aggregated data provided, no need for ethical approval.
North America		
Washington state, USA	No	Research did not include human subjects, IRB review was not required.
Latin America & Caribbean		
Mexico City, Mexico	Yes	Ethical approval was obtained from the IRB of the National Institute of Perinatology on May 4th, 2021 (2021-1-21).
Sub-Saharan Africa		
Ghana	Yes	The study was approved by the Ghana Health Service Ethics Review Committee (No. GHS-ERC 006/03/21).
Kenya	Yes	The study was approved by Jomo Kenyatta University of Agriculture and Technology Institutional Ethics Review Committee.
Nigeria		
Ibadan	Yes	The protocol was approved by University of Ibadan/University College Hospital Ibadan Ethics Review Committee UI/EC/21/0107.
Jos University	Yes	Ethical approval was obtained from Jos University Teaching Hospital, Bingham University Teaching Hospital Jos, and Plateau State Specialist Hospital.
Uyo Teaching Hospital	Yes	Ethical approval was obtained from the University of Uyo Teaching Hospital Ethical Review Board, Reference number UUTH/AD/96/Vol XXI/522. Permission was also obtained from the Akwa Ibom State Ministry of Health.
Uganda	No	No ethical approval needed. We obtained administrative clearance and reviewed records from the Department of Obstetrics and Gynaecology.

Supplementary References

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