PEER REVIEW HISTORY

ARTICLE DETAILS

TITLE (PROVISIONAL)	How many infants may have died in low- and middle-income countries in 2020 due to the economic contraction accompanying the COVID-19 pandemic? Mortality projections based on forecasted declines in economic growth
AUTHORS	Shapira, Gil; de Walque, Damien; Friedman, Jed

VERSION 1 – REVIEW

REVIEWER	Moloci, Nicholas Regents of the University of Michigan, Urology, Dow Division of HSR
REVIEW RETURNED	28-Mar-2021

GENERAL COMMENTS	Reviewer Name: Nicholas Moloci Institution and Country: Department of Health Policy and Management, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina, United States and Dow Division of Health Services Research, Department of Urology, University of Michigan Medical School, Ann Arbor, Michigan, United States General Comments: In the presented manuscript “Projecting excess infant mortality in low- and middle-income countries during the COVID-19 pandemic based on forecasted declines in economic growth” the authors look to examine the impact of economic downturn caused by to the COVID-19 pandemic. The authors use birth histories reported by the Demographic and Health Surveys conducted in low and middle-income countries. The authors then estimate the impact of GDP per capita on infant mortality rate. Based on this, the authors then estimate the potential excess infant mortality caused due to economic downturns that potentially will occur due to the pandemic. Overall, I found this article to be very interesting. It highlights the connection of healthcare systems to GDP and the profound impacts that a pandemic can have on it. There are some areas that I believe can be made clearer to help improve this manuscript. I found myself wanting more details within the methods section. Some key areas where I would like to see more elaboration: more information on the data source that was used, the level at which this analysis was conducted, and how the estimates and their confidence intervals were calculated. Detailed Comments: What are the authors thoughts on the impact of GDP/Pandemic on the number of child births? Would a possible downturn in this led to a downturn in infant mortality? What would the impact be for any financial stimulus?

	How accurate are the economic IMF growth projections in general? In economic downturns? If their measures are not accurate compared to actual results, this could lead to problems in later steps. Following same theme, how accurate are the UN World Population Prospects? During financial downturns? Would it be possible to conduct a robustness check on your methods by testing it with the financial recession that started in 2008/09? In appendix table A1 it appears that countries have different years of data available. Is this due to the data source? Or was there a method in picking specific years for each country? If so, what is that method? Page 4 Line 48, you may want to state the GDP range of the different groups. Also, could the authors please clarify the difference between low, lower-middle and low- and middle-income groupings (is this just a combination of the two previous groups). Page 5 Line 5, is the estimate for infant mortality an aggregate level measure for all countries? I see in table 1 that there are specific estimates for each group but not sure at what level the regression is done, the group or country level. Have the authors considered taking a random slopes approach for each country/group? How are the standard errors and confidence intervals being calculated for each group/group? Thoughts on bootstrapping these values? Page 5 Line 40, Uncertain how the values of 0.48, 0.24 and 0.16 in infant mortality per 1,000 children born in low- lower middle-and upper-middle-income countries, respectively, correlate with the Table 1 results of -46.85, -23.73, -16.08 and -23.12 low- lower middle- upper-middle and low- and middle income countries. Are these the same but on a different scale (logGDP vs GDP)? Also how is the low- and middle income values being calculated? Seems odd that the composite is lower (-23.12) than its parts (-46.85 and -23.73). In table 1 please define the value under the estimate (SD/SE?) Page 6 Line 20, Found this section to be a bit confusing. Could use some clarification. In this section I'm not certain what the comparison to 2019 is trying to demonstrate. Is it that the mortality rates for 2020 are higher than those in 2019? How do those values compare to the ones within table 1, are they the same scale? You list a total number of infant deaths in 2019, however, I see no total listed for 2020. Table 2: Were these values from aggregating each individual country or specific estimates for each region/group? References 19-20, formatting issue with all capitalization

REVIEWER	Reyes-Santías, Francisco Universidad de Vigo, Organización de Empresas e Mercadotecnia
REVIEW RETURNED	17-Apr-2021

GENERAL COMMENTS	REVIEW REPORT FOR THE STUDY "PROJECTING EXCESS INFANT MORTALITY IN LOW- AND MIDDLE-INCOME COUNTRIES DURING THE COVID-19 PANDEMIC BASED ON FORECASTED DECLINES IN ECONOMIC GROWTH" The paper "Projecting excess infant mortality in low- and middle-income countries during the COVID-19 pandemic based on forecasted declines in economic growth", performs regression

	models with country-specific fixed-effects and flexible time trends through a cubic time trend to estimate the impact of GDP per capita on infant mortality rate. Authors estimate a 6.8% increase in the total number of infant deaths expected in 2020 and show that a 1% decrease in GDP per capita would be associated with 0.23 increase in infant mortality per 1,000 children born in low- and middle-income countries. Title and summary. The title and abstract express well the object of study, objectives and results of the article. Structure of the article. The contents are well organized and they adhere to the IMRaD structure. It include a theoretical framework of the research problem but at this point I suggest the authors incorporate two bibliographic references that I miss in the text: The recession-mortality nexus and Covid-19. Sebastian Doerr; Boris Hofmann. BIS Bulletins, Nº 35. Bank for International Settlements. 2020. Combatting COVID-19's effect on children. Tackling coronavirus (COVID-19) Getting it right and emerging stronger. OECD 2020. The impact of the COVID-19 pandemic on maternal and perinatal health: a scoping review. Kotlar B, Gerson E, Petrillo S, Langer A, Tiemeier H. Kotlar B, Gerson E, Petrillo S, Langer A, Tiemeier H. Reprod Health. 2021 Jan 18;18(1):10. Focusing the opportunity of the study, it must be said that it is a useful work since the knowledge of the extent to which the impact of the economic crisis as a consequence of the Covid-19 pandemic and the lack of health care resources in low- and middle-income countries on the infant mortality ratio compared to pre pandemic figures is of interest to decision-makers. In that sense, authors should associate some hypotheses with the object of the study. Materials and methods. Regarding the material and methods section, it seems interesting to evaluate for the trend analysis an analysis of linear joinpoint regression and the annual percentage has been calculated of change by means of generalized linear models, assuming a Poisson distribution and testing its results compared with the methodology presented in the study. The MLG has been tested in similar studies with a good behavior of the equations. Results. The results are significant and they are presented in an adequate and understandable way not only through narration, but also with self-explained tables and figures that are also well elaborated in terms of presentation, but it would be interesting if they incorporated title and source. The results justify and relate to the objectives and methods. Discussion. The discussion appropriately compares the study results with other works, highlighting the main study findings. 69.5% of the bibliography cited in the study belongs to the previous five years. However, I suggest including the previously referred bibliographic references in the discussion: The recession-mortality nexus and Covid-19. Sebastian Doerr; Boris Hofmann. BIS Bulletins, Nº 35. Bank for International Settlements. 2020. Combatting COVID-19's effect on children. Tackling coronavirus (COVID-19) Getting it right and emerging stronger. OECD 2020. The impact of the COVID-19 pandemic on maternal and perinatal health: a scoping review. Kotlar B, Gerson E, Petrillo S, Langer A, Tiemeier H. Kotlar B, Gerson E, Petrillo S, Langer A, Tiemeier H. Reprod Health. 2021 Jan 18;18(1):10.

	The conclusions seem adequately related to the objective. Overall, it is an interesting study, and should be considered for publication in BMJ Open, once the minor revisions proposed have been resolved.

VERSION 1 – AUTHOR RESPONSE

Reviewer 1's comments

General Comments:
There are some areas that I believe can be made clearer to help improve this manuscript. I found myself wanting more details within the methods section. Some key areas where I would like to see more elaboration: more information on the data source that was used, the level at which this analysis was conducted, and how the estimates and their confidence intervals were calculated.
Response: Thank you for your careful review and thoughtful comments. We hope that the revised manuscript is clearer and includes the information you found missing in the previous version.

Detailed Comments:
What are the authors thoughts on the impact of GDP/Pandemic on the number of child births? Would a possible downturn in this led to a downturn in infant mortality?
Response: This is an excellent question and we agree that fertility related behavioral responses to the COVID-19 pandemic and resultant economic contraction will likely take place. This, in turn, may affect the estimated GDP-IMR relationship through changing differential selection into fertility. These potential changes in the composition of birth mothers would start to be expressed at the beginning of 2021. This is one reason why, in this paper, we focus only on the short-term impacts on infant mortality during the year 2020. While COVID-19 was first detected in the end of 2019, the outbreak was declared as pandemic only in March 2020. This is also the month in which most countries reported index cases and imposed restrictions to contain the virus' spread. Any change in the composition of birth mothers would not emerge until the start of 2021. We now address this point in the Discussion section:

> "Longer-term impacts on the number of infant deaths could also occur through changes in fertility behavior but should not affect our projections for 2020. Although COVID-19 was first detected in the end of 2019, the outbreak was declared as pandemic only in March 2020. If there were impacts on fertility, they would impact births and infant mortality in 2021."

What would the impact be for any financial stimulus?
Response: We feel the impact of financial stimulus is outside the scope of our study, although we expect that any financial protection instituted in response to COVID-19 would likely blunt some of the projected effects, if not mitigate them entirely if well targeted and of sufficient value. In our discussion, we make the call for strengthening social safety nets in anticipation that income support and increased food security would likely mitigate the mortality projected here.

> **"**As countries, health systems, and the wider global community continue efforts to prevent and treat COVID-19, we should also consider resources to stabilize health systems and strengthen social safety nets in order to mitigate the human, social and economic consequences of the pandemic and related lockdown policies."

How accurate are the economic IMF growth projections in general? In economic downturns? If their measures are not accurate compared to actual results, this could lead to problems in later steps.
Following same theme, how accurate are the UN World Population Prospects? During financial downturns?
Response: This is an important concern, thank you for raising it. The IMF growth projections are a key input for this exercise, and unfortunately there is surprisingly little assessment on the accuracy of such forecasts. There appears to be little systematic bias, in so far as the mean error rate is close to zero, according to a review by the Bloomberg News (https://www.bloomberg.com/graphics/2019-imf-forecasts/), and the average error rate has been declining over time. These are both pieces of good

news for our exercise as whatever forecasting error may increase the uncertainty of a central estimate but suggest little bias. It does seem that, at times of economic crisis and heightened uncertainty, the growth forecast error rate marginally increases for low-income countries (Eicher et al, 2019).

Regarding the accuracy of UN birth projections, there is also a surprisingly thin recent literature that investigates this specific question. One relatively recent paper explored the accuracy of UN population projections over 1950-1995 (Keilman, 2001) and finds that the mean absolute projection errors for regional population has declined dramatically in the 50 years studied with the global absolute error rate declining to less than 1% by the 1970s (and the mean error rate close to zero). Of course, errors to birth counts, specifically, may be greater and indeed the same study finds a mean percentage error of 3% in five year projections of the 0-4 years population (note that here the mean systematic error is not zero but slightly positive). However, this reported error rate is the average over the 1950-1995 period and has likely come down substantially for the 2015-2020 period.

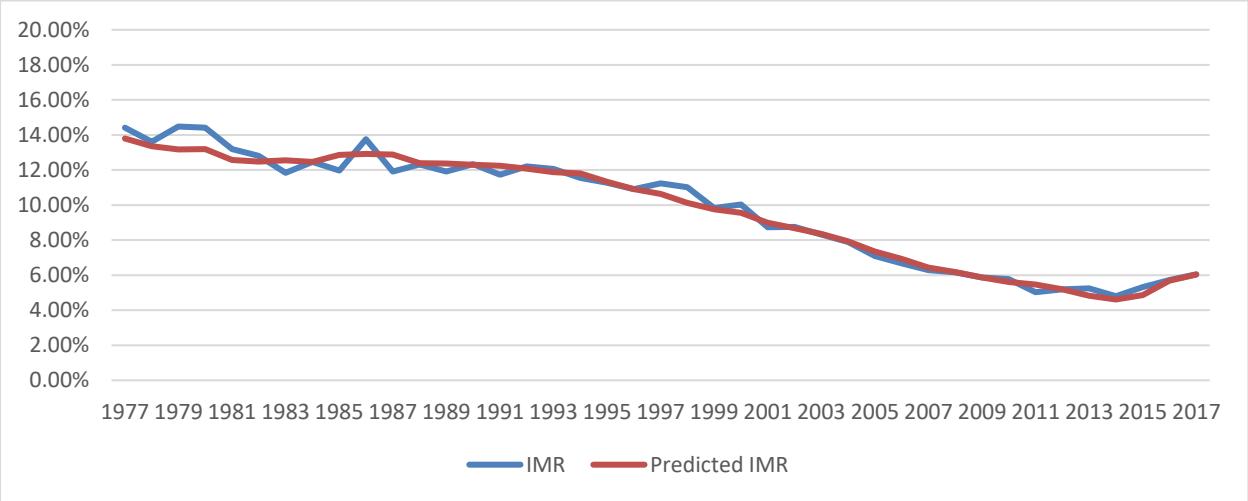
We take these concerns further by specifically modelling this uncertainty in Monte Carlo simulations described below.

Eicher, T. S., Kuenzel, D. J., Papageorgiou, C., & Christofides, C. (2019). Forecasts in times of crises. *International Journal of Forecasting*, *35*(3), 1143-1159.

Keilman, N. (2001). Data quality and accuracy of United Nations population projections, 1950-95. *Population Studies*, *55*(2), 149-164.

Would it be possible to conduct a robustness check on your methods by testing it with the financial recession that started in 2008/09?
Response: This is a compelling suggestion that we have explored. We began an inquiry prompted by this comment first by exploring how past events of deviations of economic growth from trend correlate with IMR changes. Interestingly, the average economic performance in 2008/2009 for the countries in our data is not particularly negative. Our (birth-weighted) GDP deviation from trend for 2009 is -.0035 in log terms, so only a slight decline in economic performance. This is reflected in official world growth records for that period where, while the high-income world experienced a large contraction of -3.3%, low- and middle-income countries saw an average positive growth of 2.4%.

Second, we continued by exploring the general goodness of fit of our parametric model on the incidence of infant mortality as reported in the pooled DHS datasets. The figure below shows the annual infant mortality rate reported in the data (in blue) and the mortality rate predicted by our model, for low income countries. We excluded the start and end years in the data, 1974 and 2018, for which only a few births were reported. The figure shows the predicted mortality likelihood almost exactly matches the reported figures. For 2008 and 2009, the mortality likelihoods reported in the data are 6.16% and 5.86%, respectively. The likelihoods predicted by the model are 6.17% for 2008 and 5.86% for 2009. We find similar results when considering the rest of the country-level income groups.



We hope to have reassured you regarding the goodness of fit of our model. However, we feel this figure is not central to our short paper and so leave it out. One interpretive complication is that for each year we have a different composition of countries, given the timing of the implementation of the DHS surveys in each country. This complicates an interpretation of the overall trend. For example, the observed increase in mortality likelihood between 2015 and 2017 is due to a change in the composition of countries rather than to an increase infant mortality rate for all low-income countries.

In appendix table A1 it appears that countries have different years of data available. Is this due to the data source? Or was there a method in picking specific years for each country? If so, what is that method?

Response: The years mentioned in Appendix Table A1 are the years in which the Demographic and Health Surveys were conducted in each country. We included all available surveys. Moreover, please note that we use the retrospective birth histories to create birth and infant mortality data for the 11 years preceding each survey. We revised the footnote of the Appendix Table A1:

> **"**The years denote the timing of survey implementation in each country. Some surveys spanned over more than one calendar year. In these cases, the last year of the survey is indicated. For the analysis, retrospective birth histories are used to create birth and infant mortality data for the 11 years preceding each survey."

Page 4 Line 48, you may want to state the GDP range of the different groups. Also, could the authors please clarify the difference between low, lower-middle and low- and middle-income groupings (is this just a combination of the two previous groups).

Response: Thank you for this suggestion, we now include the definition of the different groups in that paragraph:

> **"**Low-income economies are defined by a gross national income (GNI) per capita of less than 1,035 USD in 2019. Lower middle-income economies are defined by a GNI between 1,036 and 4,045 USD and the range for upper middle-income economies is between 4,046 and 12,535 USD."

The low and middle-income category is the combination of the three groups: low-income, lower middle-income and upper-middle income.

Page 5 Line 5, is the estimate for infant mortality an aggregate level measure for all countries? I see in table 1 that there are specific estimates for each group but not sure at what level the regression is done, the group or country level.

Response: The regressions were run separately for the country groups (the coefficients of these separate regressions are presented in Table 1). In the Data and Methods section, we write:

> "We estimate the semi-elasticity of infant mortality to aggregate income decline separately by country income level, as classified by the World Bank 2020 income groups."

Then, we projected excess infant mortality in each country, using the estimated coefficient for that country income level. The results presented in Table 2 are aggregations of the country-level projections presented in Appendix Table A2. We added a sentence to clarify this:

> **"**The results by income group and region presented in Table 2 are aggregations of the country level projections presented in Appendix Table A2."

Have the authors considered taking a random slopes approach for each country/group?

Response: Thank you for this question. First, let us correct an omission from our earlier submission in so far as the stated specifications did not have a country subscript on the time trend terms. However, the analysis always included a country specific time trend. With such flexible trends we essentially have an approach similar in spirit to random slopes for the effect of time on mortality likelihood. Regarding a random slope approach to the effect of economic growth (or GDP variation from trend), we essentially allow the slope to vary by national income groups through regressions stratified by income category. Allowing the slope to vary at a smaller group level, such as country, will likely introduce a significant degree of noise. We use the income group level to extract the GDP-IMR signal from the underlying noise at a level of disaggregation that we still be believe to be meaningful. We hope our reasoning is clear and would be happy to clarify further if necessary.

How are the standard errors and confidence intervals being calculated for each group/group?

Response: The confidence intervals are calculated at the country level, based on the standard error estimated for each income group. To project excess mortality, we multiply the estimated β coefficient from the regression model by the projected economic shortfall and the projected number of births:

$$\beta \times \text{shortfall} \times \text{births}$$

Define SE to be the standard error of the β coefficient. The upper bound of the confidence interval is calculated by

$$(\beta + 1.96 \times \text{SE}) \times \text{shortfall} \times \text{births}$$

The lower bound of the confidence interval is calculated by

$$(\beta - 1.96 \times \text{SE}) \times \text{shortfall} \times \text{births}$$

For the aggregated upper bound of the confidence interval presented in Table 2, we add all the country-level upper bound. For the lower bound, we add all the country-level lower bounds.

Note that we feel these bounds are quite conservative (i.e. wide) in so far as we ascribe one impact estimate (β) to all countries, or to all countries of a certain category (depending on the analysis). If instead, each country receives its own draw of β, then there should be tighter confidence bounds. To explore this further, and to incorporate the uncertainty of growth and demographic projections that the reviewer has raised above, we consider Monte Carlo simulations that have country-specific realizations of the estimated beta as well as uncertainty in both the country-specific growth and birth projections. Specifically we simulate a draw for each country from the estimated distribution of the β, draws for growth projection that are uniformly distributed around the projection at +- 1.5 percentage point, and draws for the birth projection that are uniformly distributed around the projection y at +-4 percent. The degree of uncertainty for both the growth and birth projections is informed by the literature we discuss to your question above.

After 10,000 simulations we obtain a 95% CI of total excess deaths to be (222514, 312525). This is substantially narrower than the reported CI of (112000, 422415). This is because, despite the increased uncertainty on birth and growth projections, allowing for uncorrelated country-specific β's produces tighter bounds than the perfectly correlated β realizations that we apply in the main estimates. The modeled uncertainty is still largely due to variation in the β's. If instead we model only uncertainty in birth and growth projections, while fixing the β's, we get a confidence bound spanning (251588, 283106).

We have now modified the discussion in the paper to include a fuller discussion of the reported CIs, how they are computed, and issues around uncertainty in growth and birth projections. Specifically we add these two paragraphs to the discussion:

> "Regarding the reported confidence intervals for projected excess infant deaths in Table 2, note that these bounds may be regarded as conservative. This is because we first apply the 5th percentile lower bound and then the 95th percentile upper bound estimate of the mortality semi-elasticity to the projected growth contractions for all countries in order to estimate the bounds, thus imposing a perfect correlation of semi-elasticities across countries. If instead, each country receives its own independent draw from the distribution of semi-elasticities then there will be significantly tighter confidence bounds in expectation.
>
> On the other hand, there may also be forecast error in either the country-level economic growth projections or in the projections of number of births, which is not directly modeled. Previous literature suggests these forecast errors have an expected mean of zero, with most deviations from forecast on the order of plus/minus one percentage point of economic growth or plus/minus three percent of total births (24) (25). To explore further the role of uncertainty in economic and demographic projections, we consider Monte Carlo simulations that model country-specific growth and birth projections with a slightly larger anticipated degree of error. Specifically, we simulate a draw for each country from growth projections that are uniformly distributed around the projection at +- 1.5 percentage points, and draws for the birth projection that are uniformly distributed around the projection at +- 4 percent. After 10,000 simulations we obtain a 95% CI of total excess deaths to be (251588, 283106). substantially narrower than the reported CI of (112000, 422415). This suggests that uncertainty in the true value of the growth-IMR semi-elasticity is the most influential parameter driving uncertainty in the projected total number of indirect infant deaths."

We hope you find these changes to the paper to be sufficient and are happy to discuss further.

Page 5 Line 40, Uncertain how the values of 0.48, 0.24 and 0.16 in infant mortality per 1,000 children born in low- lower middle-and upper-middle-income countries, respectively, correlate with the Table 1 results of -46.85, -23.73, -16.08 and -23.12 low- lower middle- upper-middle and low- and middle income countries. Are these the same but on a different scale (logGDP vs GDP)? Also how is the low- and middle-income values being calculated? Seems odd that the composite is lower (-23.12) than its parts (-46.85 and -23.73).
Response: First, we would like to apologize for a typo that we spotted thanks to this comment. In Table 1, the correct coefficient is -47.85. Second, the results presented in the table are the results of the regression estimation according to the specification presented in the Data and Methods section. The way to interpret these coefficients is that a 100% increase in GDP per capita would decrease infant mortality by 47.85 deaths per 1000 live births. In the text, we report the impact of each percentage change in GDP per capita and therefore the coefficients are divided by 100 and are rounded in the text.

In table 1 please define the value under the estimate (SD/SE?)
Response: Thank you for this clarifying question. In the footnotes for Table 1, we added a sentence stating that "Standard errors are presented in parentheses."

Page 6 Line 20, Found this section to be a bit confusing. Could use some clarification. In this section I'm not certain what the comparison to 2019 is trying to demonstrate. Is it that the mortality rates for 2020 are higher than those in 2019? How do those values compare to the ones within table 1, are they the same scale? You list a total number of infant deaths in 2019, however, I see no total listed for 2020.
Response: We apologize for the confusion. The objective in comparing the predicted excess mortality to the mortality in 2019 is to calculate the overall percentage increase in infant mortality. In other words, 267,208 is a very large number of excess infant deaths, but how does it compare with the expected annual number of infant deaths in the absence of the pandemic?
The year 2019 is chosen because it's the last year before the pandemic and therefore the number of infant deaths in that year is expected to be similar to that in 2020. We have revised the corresponding paragraph and we hope it is clearer now.

Table 2: Were these values from aggregating each individual country or specific estimates for each region/group?
Response: The values reported in Table 2 represent aggregation of the individual country estimates for each region or income group

References 19-20, formatting issue with all capitalization

Response: Thank you for spotting that. It has been fixed.

Reviewer 2's comments

Structure of the article. The contents are well organized and they adhere to the IMRaD structure. It include a theoretical framework of the research problem but at this point I suggest the authors incorporate two bibliographic references that I miss in the text:
The recession-mortality nexus and Covid-19. Sebastian Doerr; Boris Hofmann. BIS Bulletins, Nº 35. Bank for International Settlements. 2020.
Combatting COVID-19's effect on children. Tackling coronavirus (COVID-19) Getting it right and emerging stronger. OECD 2020.
The impact of the COVID-19 pandemic on maternal and perinatal health: a scoping review. Kotlar B, Gerson E, Petrillo S, Langer A, Tiemeier H. Kotlar B, Gerson E, Petrillo S, Langer A, Tiemeier H. Reprod Health. 2021 Jan 18;18(1):10.
Response: Thank you for these suggestions. We now cite the two papers. As for the OECD report, we have reviewed it and decided, since it is not directly related to the topic of our study, not to cite that one.

Focusing the opportunity of the study, it must be said that it is a useful work since the knowledge of the extent to which the impact of the economic crisis as a consequence of the Covid-19 pandemic and the lack of health care resources in low- and middle-income countries on the infant mortality ratio compared to pre pandemic figures is of interest to decision-makers.In that sense, authors should associate some hypotheses with the object of the study.
Response: Thank you for this perspective. We hope the revised manuscript makes clear that our study revisits a hypothesis that was already tested before, namely is there a link between aggregate income shocks and infant mortality? And further, if so, what magnitude of additional infant death might we expect given the COVID-19 pandemic related economic contraction? The contribution of our study is twofold. First, we update previous estimates of the relationship between GDP fluctuations and infant mortality, using a larger and more recent dataset. Second, we use this estimate to project infant mortality in 2020, a period of considerable contraction in the global economy.

Materials and methods.
Regarding the material and methods section, it seems interesting to evaluate for the trend analysis an analysis of linear joinpoint regression and the annual percentage has been calculated of change by means of generalized linear models, assuming a Poisson distribution and testing its results compared with the methodology presented in the study. The MLG has been tested in similar studies with a good behavior of the equations.
Response: Thank you for this interesting suggestion. We chose the linear probability model with country-specific flexible polynomial controls for time in part to be consistent with previous peer reviewed studies (Baird, Friedman and Schady 2011; Friedman and Schady 2013). One of the contributions of our study is to provide an up-to date analysis of the relationship between aggregate income shocks and infant mortality, using an expanded and more recent dataset. Moreover, the previous studies demonstrated the robustness of results to different empirical specifications. For example, Friedman and Schady (2013) show similar result generated by estimation of Probit and linear probability models, as well as polynomials in time of order 1 to order 3. In this study, while we choose to report the impact estimates of GDP shocks on infant mortality using a time polynomial of order 3, the estimated coefficients are not significantly different from the estimated using a time polynomial of order 2 or order 4. As we describe in our responses to the comments of the other reviewer, and demonstrate in the figure, our estimated model fits very well the data.

For these reasons, we decided to not include an additional model specification in the paper, such as the flexible spline approach of joinpoint regression, in part because we feel a strength of the paper is its brevity. If the reviewer elaborates regarding their concerns with the current model, we would be happy to address these concerns.

Baird, Sarah, Jed Friedman, and Norbert Schady. "Aggregate income shocks and infant mortality in the developing world." *Review of Economics and statistics* 93, no. 3 (2011): 847-856.

Friedman, Jed, and Norbert Schady. "How many infants likely died in Africa as a result of the 2008–2009 global financial crisis?." *Health Economics* 22, no. 5 (2013): 611-622.

Results.
The results are significant and they are presented in an adequate and understandable way not only through narration, but also with self-explained tables and figures that are also well elaborated in terms of presentation, but it would be interesting if they incorporated title and source. The results justify and relate to the objectives and methods.
Response: Thank you for this insight. In the footnotes of the Tables, we added sources of the data presented and clarified the methods. We hope now that the tables are self-explained.

Discussion.
The discussion appropriately compares the study results with other works, highlighting the main study findings. 69.5% of the bibliography cited in the study belongs to the previous five years. However, I suggest including the previously referred bibliographic references in the discussion:
The recession-mortality nexus and Covid-19. Sebastian Doerr; Boris Hofmann. BIS Bulletins, Nº 35. Bank for International Settlements. 2020.

Combatting COVID-19's effect on children. Tackling coronavirus (COVID-19) Getting it right and emerging stronger. OECD 2020.
The impact of the COVID-19 pandemic on maternal and perinatal health: a scoping review. Kotlar B, Gerson E, Petrillo S, Langer A, Tiemeier H. Kotlar B, Gerson E, Petrillo S, Langer A, Tiemeier H. Reprod Health. 2021 Jan 18;18(1):10.
Response: Thank you. As we wrote above, we now cite two of the suggested studies in the introduction section.

VERSION 2 – REVIEW

REVIEWER	Moloci, Nicholas Regents of the University of Michigan, Urology, Dow Division of HSR
REVIEW RETURNED	01-Jul-2021

GENERAL COMMENTS	After reviewing the updated manuscript and the authors' responses, the manuscript is much improved. I appreciate the authors additional work on the goodness of fit of their model. The authors have improved the clarity of the methods and results section.

REVIEWER	Reyes-Santías, Francisco Universidad de Vigo, Organización de Empresas e Mercadotecnia
REVIEW RETURNED	04-Jul-2021

GENERAL COMMENTS	REVIEW REPORT FOR THE STUDY BMJopen-2021-050551.R1 "HOW MANY INFANTS MAY HAVE DIED IN LOW- AND MIDDLE-INCOME COUNTRIES IN 2020 DUE TO THE ECONOMIC CONTRACTION ACCOMPANYING THE COVID-19 PANDEMIC? MORTALITY PROJECTIONS BASED ON FORECASTED DECLINES IN ECONOMIC GROWTH". The paper "How many infants may have died in low- and middle-income countries in 2020 due to the economic contraction accompanying the COVID-19 pandemic? Mortality projections based on forecasted declines in economic growth", study the indirect impact of the economic crisis subsequent to the Covid-19 pandemic on infant mortality in low and middle-income countries. The study uses the country's GDP as a measure of the economic crisis and the evaluation of its impact on infant mortality is carried out through a logit analysis. Title and summary. The title and abstract express well the object of study, objectives, and results of the article. Structure of the article. The contents are well organized and they adhere to the IMRaD structure. It include a theoretical framework of the research problem but at this point I suggest the authors incorporate a bibliographic reference that I miss in the text: Kabir M, Saqib MAN, Zaid M, Ahmed H, Afzal MS. COVID-19, economic impact and child mortality: A global concern. Clin Nutr. 2020 Jul;39(7):2322-2323. doi: 10.1016/j.clnu.2020.05.027. Epub 2020 May 30. PMID: 32499056; PMCID: PMC7260517. Focusing the opportunity of the study, it must be said that it is a useful work because the studies the determinants of infant mortality from the economic point of view, understanding GDP as a variable that measures the economic crisis resulting from the effects of Covid-19.

	In that sense, hypotheses could be established in a clearer way for the reader than as they are intended to be established (i.e. "the relationship between aggregate income shocks and mortality). Materials and methods. Regarding the material and methods section, the methodology is tailored to the object of study and the objectives and is explained in a transparent manner while it has been validly applied to guarantee the results. However, I suggest that the authors clarify some issues in the text: 1.- The authors must take into account other variables that are related to GDP and infant mortality, such as health spending. For example, almost half (44%) of deaths of children under five years of age worldwide correspond to newborns. This may be because many sub-Saharan African countries have significant deficits in terms of access to basic social services, such as education and health services, clean water, adequate nutrition, and hygiene and sanitation services. But, while life expectancy at birth is among the lowest in the world, while the infant mortality rate decreased 21 percentage points. On the other hand, around 45% of all deaths of children under five years of age are associated with malnutrition at these ages, and a child who is exclusively breastfed is 14 times less likely to die in the first six months of life. life than one who does not receive that type of food. Therefore we suggest that the study incorporate the variable Healthcare expenditures. 2.- Inequality should also be taken into account using, for example, the Gini index. And an indicator of poverty such as per capita consumption 3.- It is unclear how the authors take into account the effect of delay in determining the phase of the economic cycle. Results. The results are significant and they are presented in an adequate and understandable way not only through narration but also with self-explained tables and figures that are also well elaborated in terms of presentation. The results justify and relate to the objectives and methods and the results are of sufficient social interest. Discussion. The discussion appropriately compares the study results with other works, highlighting the main study findings. 68% of the bibliography cited in the study belongs to the previous five years. But it is suggested to the authors to incorporate the full bibliographic reference for references 14, 17 and 23.. The conclusions are adequately related to the objective. Overall, it is an interesting study and should be considered for publication in BMJ Open, once the minor revisions proposed have been resolved.

VERSION 2 – AUTHOR RESPONSE

Reviewer 2's comments

Structure of the article. The contents are well organized and they adhere to the IMRaD structure. It include a theoretical framework of the research problem but at this point I suggest the authors incorporate a bibliographic reference that I miss in the text:
Kabir M, Saqib MAN, Zaid M, Ahmed H, Afzal MS. COVID-19, economic impact and child mortality: A global concern. Clin Nutr. 2020 Jul;39(7):2322-2323. doi: 10.1016/j.clnu.2020.05.027. Epub 2020 May 30. PMID: 32499056; PMCID: PMC7260517.

Response: Thank you for suggesting this reference. In discussion of the study limitations in the Discussion Section, we added the following text that includes the suggested reference:

> "Finally, economic contractions in high-income countries might reduce foreign aid to lower-income countries which in turn can increase mortality (Kabir et al. 2020). Our model does not account for such mechanism that might arise in a global economic crisis as we assume that a country's infant mortality rate is only affected by its own GDP."

Focusing the opportunity of the study, it must be said that it is a useful work because the studies the determinants of infant mortality from the economic point of view, understanding GDP as a variable that measures the economic crisis resulting from the effects of Covid-19. In that sense, hypotheses could be established in a clearer way for the reader than as they are intended to be established (i.e. "the relationship between aggregate income shocks and mortality).

Response: We begin the Data and Methods section by stating that the goal of the regression analysis is "To estimate the impact of changes in aggregate income on infant mortality". We hope this further clarifies the hypothesized relationship between the main variables of interest. In addition, we have added the following sentence in the same paragraph to underscore that the study hypothesizes a link between aggregate income changes and infant mortality:

> "β is the coefficient of interest, describing the relationship between aggregate income shocks and infant mortality. "

However, I suggest that the authors clarify some issues in the text:

1.- The authors must take into account other variables that are related to GDP and infant mortality, such as health spending. For example, almost half (44%) of deaths of children under five years of age worldwide correspond to newborns. This may be because many sub-Saharan African countries have significant deficits in terms of access to basic social services, such as education and health services, clean water, adequate nutrition, and hygiene and sanitation services. But, while life expectancy at birth is among the lowest in the world, while the infant mortality rate decreased 21 percentage points. On the other hand, around 45% of all deaths of children under five years of age are associated with malnutrition at these ages, and a child who is exclusively breastfed is 14 times less likely to die in the first six months of life. life than one who does not receive that type of food. Therefore we suggest that the study incorporate the variable Healthcare expenditures.

Response: Thank you for these thoughts and the request to clarify these issues in the text. We have now included a more careful discussion of relevant macro-constructs that determine the production of child health, this includes public health sector spending, private spending on health and nutrition, donor health aid, public and private spending on related sectors and services such as water and sanitation. In many ways, these components of GDP that are more directly tied to child survival are the more relevant constructs to explore. However, this data does not exist in a systematic and standardized form for the countries and times periods considered. Therefore, we choose to follow the existent literature and explore summary measures of national economic output, GDP, and the relation to infant survival. How total spending directly relevant to health ("health and nutrition spending" in short) covaries with aggregate economic fluctuations, and how sensitive the likelihood of infant survival is to such "health and nutrition spending", is an interesting and important topic, but we feel beyond the scope of this note given the paucity of existent data.

We hope you find the expanded discussion suitable. We have now added the following paragraph to the discussion section:

> "Regarding limitations of the analysis, one refinement of our estimation approach would consider the relevant expenditure categories that directly determine the production of child health, rather than overall expenditure as captured in GDP. Relevant expenditure categories include public health sector spending, private spending on health and nutrition, foreign assistance in the form of health aid, and public and private spending on related sectors and services such as water and sanitation. It is these components of GDP that are more directly tied to child survival and would likely exhibit a more predictive relationship to infant mortality than overall GDP exhibits. Unfortunately, this more granular data does not exist in a systematic and standardized form for the countries and time periods considered, nor are there standard future projections of such components. Therefore, we follow the existent literature

and explore the relation between a widespread summary measures of national economic output, GDP, and infant survival."

2.- Inequality should also be taken into account using, for example, the Gini index. And an indicator of poverty such as per capita consumption

Response: This is an interesting suggestion, but we feel that such analysis goes beyond the scope of the current study and presents some empirical challenges. We agree that aggregate economic shocks will likely differentially impact households of different wealth levels, thereby also influencing the subsequent distribution of wealth. Therefore, taking into account inequality requires additional modeling as aggregate income shocks will not just impact contemporaneous mortality but future mortality indirectly though changes on subsequent inequality.

Perhaps more importantly, we do not have the necessary data to easily include a summary inequality measure such as the Gini Coefficient within our estimation framework. The Demographic and Health Surveys allow us to construct annual birth and mortality indicators from retrospective reporting of fertility histories of women. However, the data does not include per capita consumption or even wealth status at the annual level for the same years. Standard macro-economic datasets such as PovCalNet (iresearch.worldbank.org/PovcalNet/index.htm) update the national Gini coefficient only on a sporadic basis. For example, the Gini estimate for India is only updated in years 1987, 1993, 2004, 2009, and 2011.

We have now added the following paragraph to the discussion section:

"An extension of our approach may also consider country characteristics that likely mediate the GDP-mortality relation, including measures of economic inequality. Infant mortality in more unequal countries is likely more vulnerable to economic contractions. However, here again, we do not have the necessary annual data to easily include a summary inequality measure such as the Gini Coefficient within our estimation framework. The Demographic and Health Surveys allow us to construct annual birth and mortality indicators from retrospective reports of fertility yet do not include per capita consumption or wealth status for the same years. Standard cross-country datasets such as PovCalNet (iresearch.worldbank.org/PovcalNet/index.htm) update the national Gini coefficient only on a sporadic basis. For example the Gini estimate for India is only updated for the years 1987, 1993, 2004, 2009, and 2011"

3.- It is unclear how the authors take into account the effect of delay in determining the phase of the economic cycle.

Response: Our study solely focuses on the short-term (i.e. contemporaneous) effect of aggregate income shocks on infant mortality. This approach is consistent with the existent literature that already demonstrated such impact. Moreover, the study by Baird, Friedman and Schady (2011), which we cite in our paper, demonstrates that controlling for lagged and lead fluctuations in per capita GDP do not significantly change the estimated relationship between GDP and infant mortality. There is a wide evidence base showing that the economic contraction that accompanied the COVID-19 pandemic was strongly felt at the household level in 2020 (for example, we cite Egger et al. 2021).

Taking your comment under advisement, we acknowledge that there could be delayed impacts on infant mortality, but the currently available data only allows us to estimate the impact in 2020. This is a point we address as a limitation in the discussion when we write: "Another limitation is that we only consider the short-term impact of GDP fluctuations on mortality while longer-term consequences might also exist."

The discussion appropriately compares the study results with other works, highlighting the main study findings. 68% of the bibliography cited in the study belongs to the previous five years. But it is suggested to the authors to incorporate the full bibliographic reference for references 14, 17 and 23.

Response: Thank you for spotting these errors in importing the reference information. These are fixed now.

VERSION 3 – REVIEW

REVIEWER	Reyes-Santías, Francisco Universidad de Vigo, Organización de Empresas e Mercadotecnia
REVIEW RETURNED	01-Aug-2021

GENERAL COMMENTS	Regarding the review of paper ”How many infants may have died in low- and middle-income countries in 2020 due to the economic contraction accompanying the COVID-19 pandemic? Mortality projections based on forecasted declines in economic growth” (bmjopen-2021-050551.R2), once I have read the letter of reply from the authors to my comments on the review, I understand that they have covered all my suggestions and, as far as I am concerned, my suggestion to BMJ Open is to accept the publication of the new version of the paper.