Not a Dream Wedding: The Hidden Nexus Between Climate Change and Child Marriage

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ABSTRACT

Using a structural equation model, this paper studies the unexplored relationship between climate change and child marriage. Based on a sample of 180 countries and using a variety of economic, climatic, and cultural variables, our results suggest that climate change indeed has indirect as well as direct effects on child marriage. We state that, following an indirect channel, climate change affects child marriage through climate vulnerability, which acts mainly via income reductions, which strengthen the main drivers of child marriage: gender discrimination and extreme poverty. We also conclude that of the two main drivers, gender discrimination is relatively more important than extreme poverty.

Keywords: Climate change; Child marriage; Climate vulnerability; Structural Equation Model.

JEL: C23, C33, Q54, C51.

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1 Introduction

Most of the studies examining the effects of climate change have focused on its environmental, biodiversity and natural disaster effects. The main motivation of analyzing climate change impacts is the large implications they can have on human well-being. (Pecl et al. 2017; Lamb and Steinberger, 2017). In fact, as shown by Weitzman (2011, 2014), even climate change negative impacts with very low probability of occurrence can have enormous impacts on social well-being. Moreover, climate change is a global phenomenon with very extensive possible negative impacts, and it has already caused social, sanitary and economic consequences (Carleton & Hsiang, 2016; Sellers, Ebi, & Hess, 2019). Some research highlights the fact that global warming has an impact on epidemics, deaths and violence among many other aspects (Wiley, 2020 ; Carleton & Hsiang, 2016). Moreover, socio-economic impacts of climate change, though generally not well understood, are likely to be profound and will impact humans through a variety of direct and indirect pathways (Cline, 2007; Ipcc, 2007; Stern, 2007). Additionally, as explained by (Heltberg, Siegel, & Jorgensen, 2009), the indirect effects are often hard to predict (they are the consequences of consequences) but could have the worst impacts. In particular, with the massive sanitary crisis that the world is experiencing, there is a danger of changing the pattern toward decarbonization of the economy to give priority to face the severe and extreme economic consequences of the new COVID-19 exacerbating the negative consequences of climate change.[2]

There are case studies that show evidence of the impact that climate change can have on the vulnerable population of developing countries (Ziegler, Morelli, & Fawibe, 2019) and particularly on child marriage (Alston et al., 2014; Ferdous & Mallick, 2019; Kumala Dewi & Dartanto, 2019). In fact, climate change is a global phenomenon. This is why it can have influence on any social group or economic organization in the planet. Moreover, as climate may affect almost every economic activity, it can affect human decisions through countless different direct and indirect channels. This makes quite challenging and complex the task

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[2]   https://www.theguardian.com/environment/2020/nov/09/revealed-covid-recovery-plans-threaten-global-climate-hopes

of disentangling the specific effects of the different variables involved in the impacts of climate change on child marriage, which is the main object of this report.

Using a structural equation model (SEM), we formally study the nexus between climate change and child marriage analyzing a cross-section of 180 countries for the 2017-2018 period.[3] Despite its importance, little research has examined the central question of the main drivers of child marriage and its relation -if any- to climate change.[4] The main contribution of this research is to test formally the climate change-child marriage relationship considering socioeconomic variables and indicators of vulnerability to climate change. We corroborate previous case analysis findings showing that climate change increases the risk of child marriage. We also show that the main operating channel for the studied relationship is more than a direct one, an indirect channel affecting through climate vulnerability, via income reductions, which strengthens the main driver of child marriage: gender discrimination and extreme poverty. We also performs a robustness analysis including additional covariates such as population, religious status, either if the country is muslin or not and we show also that results are free of an endogeneity problem.

In the following section, we review the literature on child marriage and climate change. This review is focused on the main determinants that have been proposed and on specifying the conceptual framework for econometrically testing the effect of climate change. In section 3, we present the method and describe the data. In section 4 we report empirical estimates of the relationship between child marriage and climate change based on information drawn from sources described in section 3. Section 5 presents some robustness checks. Finally, section 6 concludes.

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[3] We do not use panel data because in some cases climate vulnerability- the main explanatory variable- is time independent, e.g. geophysical characteristic of a country such as being an island

[4] For related literature see the recent results of Corno and Voena (2016); Corno et al (2017); and Trinh and Zhang (2020), pp.1-23.

2 Literature review

Climate change as a global phenomenon affects all countries and groups in society. However, there are countries and social groups that are more vulnerable than others, due to their particular characteristics. Within the population influenced by climate change, there are vulnerable groups in socioeconomic terms. Women and children are among the most vulnerable groups (Alston, Whittenbury, Haynes, & Godden, 2014): according to United Nations, a third of these groups are composed of children and adolescents under 19, meaning that there are about 2.5 billion of children and adolescents exposed to a great risk caused by worldwide climate changes. About 90% of those children and adolescents live in under-developed regions: all regions of Africa, Asia except Japan, Latin America and the Caribbean plus Melanesia, Micronesia, and Polynesia. About 1.1 billion of them are girls (UNICEF, 2015).

Underage women are an extremely vulnerable group in society (Akinsemolu & Obafemi, 2019; Miller et al., 2010; Servin et al., 2015; Tschakert, van Oort, St. Clair, & LaMadrid, 2013). Due to the cultural appreciation of gender and childhood existing in some countries, these vulnerability increases even more, a situation that conditions the existence of some social problems. Poverty, gender discrimination and violence are some of those problems, others also deserve attention, such as violence against women. For example, in a survey of the literature studying the vulnerability to climate change of women in developing countries, especially in India and South Asia; Yadav & Lal (2018) report severe adverse impacts not only on women's lively-hood opportunities but also on exacerbating the workload and fatigue. These factors provoke a decrease in their self-esteem and force them to undertake some high risks and hazardous activities.

Another form of violence affecting women is child marriage (CM), which receive less attention, but still exists and persists despite progress in the human development of countries (Stritof, 2019; Leonard, 1979). In fact, it is still a wide global problem. According to the Pew Research Center, the 2014 data from Census Bureau's American Community Survey, in the United States, 57,800 minors Americans of 15 to 17 years of age were married as of 2014, 5 of every 1,000 in this age group, and 55% of them were girls and 45% boys (PEW, 2016). In the rural villages of Egypt, Afghanistan, Bangladesh, Ethiopia,

Pakistan, India and the Middle East, uneducated young girls are rarely allowed out of their homes. They can only work in agricultural activities or to get married. These girls are often married off as young as 11 years old. Moreover, some families allow girls who are only 7 years old to marry (Stritof, 2017). This author explains that in Egypt and India, the legal age to be married is 16 and 18, respectively, but these legal norms are quite often ignored. He also mentions that in Afghanistan it is estimated that between 60% to 80% percent of marriages are forced by families. In fact, Afghanistan is considered one of the most dangerous countries in the world to be a woman. Many women also face forced engagement -despite it being illegal (TAF, 2017). In Bangladesh, in turn, using data from 2011, (Kamal, Hassan, Alam, & Ying, 2015) report that more than 75% of marriages can be categorized as child marriages.

Child marriage is defined as a marriage of a girl or a boy before the age of 18 and refers to both formal marriages and informal unions in which children live with a partner as if married (Parsons et al 2015). It affects both girls and boys, but it affects girls disproportionately, especially in South Asia or Africa; for example, according to UNICEF data, one out of five girls are married while still being a child. Other 20% of girls are married before the age of 18, while 5 % are married before the age of 15. It occurs in the highest proportion in Central and West Africa where 41% of girls are married before the age of 18, and 14% before the age of 15, and is not only prevalent in Africa, East Asia and the Pacific, but in Western Europe and North America as well (Koski & Heymann, 2018). In fact, through the world, 12 million girls marry before age 18, every year. CM is often associated to a common practice in South Asia and Sub-Saharan Africa (Nour, 2006; Raj, 2010), but its prevalence is not absent in other parts of the world such as Latin America (Taylor et al., 2019), United States (Le Strat, Dubertret, & Le Foll, 2011, Koski & Heymann, 2018, PEW, 2016), and many other countries (Wahhaj, 2018).

In many countries, parents encourage the marriage of their daughters while they are still children, expecting to get financial and social benefits from it, and to reduce their family´s financial burdens (UNICEF, 2005). As this UN agency states, Child marriage is in fact a

violation of human rights[5], very often provoking social isolation and early pregnancy of girls, most of them with little education, thus reinforcing the gendered nature of poverty by the expanded lack of education and vocational training. Even though the existence of a global consensus of the negative impacts of CM on children specially girls (Nour, 2009; Raj, 2010), there are several reports and research results showing several effects that impose limits on their financial independence and economic progress (Pandey, 2017). Moreover, they are more exposed to suffer physical and sexual violence (Pandey, 2016); medical problems related to juvenile pregnancy and sexual transmission diseases (Nour, 2006; Pandey, 2017); and risk of mental health (Gage, 2013; Nour, 2009; Raj, 2010). However, child marriage is so widespread in the world that some estimation indicate that 650 million girls and women alive today were married as children (UNICEF, 2020).

Underlying causes of Child Marriage are difficult to uncover. Even though there is some understanding about their consequences. Some authors have proposed conceptual frameworks that can explain their occurrence taking in consideration economic and social aspects such as poverty, aggregate income, the role of woman in society, gender equality, social status and so on (Bergstrom & Bagnoli, 1993; Malhotra, 2010; Parsons et al., 2015; Wahhaj, 2018).

All the theoretical studies mentioned above imply that a woman with scarce financial resources is likely to marry earlier, even though the relationship between income and child marriage at aggregate level is more complex and has not been sufficiently studied. It is true that most empirical studies find a negative relation at microlevel where poverty is one of the determinants of CM, but at aggregate level, the picture is not that clear.

Regarding explanations based on social norms, Seth et al. (2018), shows evidence that a patriarchal system prevent the capacity of woman to emancipate and becoming productive

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[5] Article 16 of the Convention on the Elimination of all Forms of Discrimination against Women states the right of girls and boys to be protected from child marriage. It declares: "The betrothal and the marriage of a child shall have no legal effect, and all necessary action, including legislation, shall be taken to specify a minimum age for marriage..."

citizens and from a sociological point of view, CM facilitates subordination of woman, access to social and material resources and neglecting their ability to think and act. CM also minimizes parental responsibilities toward girl´s education, developmental activities, socialization, and so forth (Subramanian, 2008). CM is often seen as a form of parental protection against parent's economic instability and protection against rape and violence (Raj & Boehmer, 2013). This vulnerabilities, however, as a justification for early marriage occur in the context gender inequalities and devaluation of the role of woman and girls (Raj, 2010).

At first glance, child marriage seems not to be related with climate change, at least not directly, but climate change has been widely accredited as having a special effect on the most vulnerable such as woman, poor people, children and the elderly (Alston et al., 2014; Bhadwal, Sharma, Gorti, & Sen, 2019). In this sense, child affected by CM, particularly girls, are among these vulnerable groups. Also, there is small but growing evidence that the effects of natural disasters such as earthquake, hurricanes, floods, etc. affect particularly to the most vulnerable groups (Kumala Dewi & Dartanto, 2019; Ziegler et al., 2019). Moreover, poor children are surely among the most vulnerable as we noted above. If at least some of these disasters are associated to climate change as several authors postulate, it seems to be logical that climate change has an effect on CM. According to some authors, natural disasters such as floods, droughts and earthquakes implies evacuation of people, destruction of crops and damage on economic activities and household welfare. The burden affects households, especially poor and vulnerable groups including children, women and the elderly. Disasters and crises have a negative effect on everyone involved. People die and get injured, lose their families and their livelihoods. But being female, and particularly being an adolescent, disasters and crises may put you at greater risk than if you are male (Kumala Dewi & Dartanto, 2019).

Moreover, recently, as pointed out by the President of the Republic of Estonia[6], climate change has become a very real and painfully existential threat and continues to have a disproportionate impact on women and children (Kaljulaid, 2020). In fact, the Covid-19 pandemic and conflicts have compounded with climate change to exacerbate existing inequities disproportionally, provoking a large increase in children, adolescents and women vulnerability (WHO/UNICEF, 2020). As a result, projections for 2020 to 2030 suggest that the economic consequences of these compounded causes could imply a significant increase in gender-based violence and, therefore, would result in an additional 13 million child marriages taking place that otherwise would not have occurred (UNFPA, 2020). The global burden of child marriage has shifted to sub-Saharan Africa, so that most recently married child brides, close to 1 in 3 are now in this region of the world, compared to 1 in 5 a decade ago; on the other hand, in Latin America and the Caribbean, the prevalence has remained stagnant for the last decade (UNICEF, 2020).

3 Methodology and data

The present study focuses in the direct and indirect effects of climate change on child marriage. We use a structural equation model (SEM) to include economic (i.e. income and poverty) and cultural variables (i.e. social norms) as mediators and moderators between climate change and CM. SEM is a statistical method to uncover complex relationships between one or more independent variables and one or more dependent variables.

In this study, statistics on two variables − child marriage under de age of 18 years old and 15 years old − are used as data on the dependent variables under analysis, together with data on the hypothesized variables as determinants or mediators and moderators of child

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[6] The Estonian President, Kersti Kaljulaid, is also the Co-Chair of the High Level Steering Group for the United Nations Every Woman Every Child Global Strategy for Women's, Children's and Adolescents' Health

marriage: gender inequality and extreme poverty . We obtained data for 180 countries from the following three organizations: UNICEF, Notre Dame Global Adaptation Initiative and the United Nations (see table 1).

Table 1: Variables in the structural equation model

Latent Variable	Unit of measurement	Source
Child marriage	Married by 18, Married by 15	UNICEF 2018
Climate change	Vulnerability	ND Gain Index
Economic variables	*GDP per capita, poverty rate*	World Bank
Social norms	Gender Equality Index	UNDP, 2018

(1) Child marriage indicators.

Married by 15 is the percentage of women aged 20 to 24 years who were first married or in union before age of 15.

Married by 18 – Percentage of women aged 20 to 24 years who were first married or in union before age of 18.

(2) Climate change

The vulnerability of a country describes the propensity or predisposition of the society to be affected negatively by climate hazards. The University of Notre Dame created an initiative called *Notre Dame Global Adaptation Initiative* (ND-Gain) which developed an index (Chen et al., 2015). *Vulnerability* – is assessed by an index, which considers six life-supporting sectors of a country: food, water, health, ecosystem services, human habitat, and infrastructure.

(3) Each sector is characterized by six indicators that represent three interrelated *components* across the sectors: 1) the *exposure* of the sector to climate-related or climate exacerbated hazards; 2) the *sensitivity* of that sector to the impacts of the hazard; and, 3) the *adaptive capacity* of the sector to cope or adapt to these impacts. If the score of a country is high, it means that the country is vulnerable to climate change (Chen et al., 2015). The higher the value of "Vulnerability" is, the higher is the impact of climate change on a country. Economic variables

Gross Domestic Product per capita in constant PPP dollars– sum of the value of everything produced in a country during a year, divided by the number of people. The unit is in international dollars, fixed 2011 prices. The data is adjusted for inflation and differences in the cost of living between countries, so-called PPP dollars.

(4) Social Norms

Gender Equality Index – measures gender inequalities in three important aspects of human development: reproductive health, empowerment, and economic status.

For 180 countries we obtained data on the percentage of women in their 20s and 24s who were married for the first time or in union before the age of 15 and 18: with an average of 3.69% for child marriage under 15 years old and 15.22% for children under 18 years old. The highest number of marriages under the age of 15 is in Chad, with 30%; and the highest percentage of marriages under the age of 18, in Niger, with 76%.

Regarding the countries with extreme values of vulnerability to climate change, Switzerland shows the lowest vulnerability with 0.27, the highest vulnerability shows Somalia with 0.68. The country with the highest gender inequality according to the Gender Inequality Index is Yemen (0.83), the lowest gender inequality in Switzerland (0.04). Considering Gross Domestic Product per capita as an economic dimension, the smallest can be found in Burundi, while the highest is Luxembourg. Summary statistics are reported in Table 2.

Table 2: Summary statistics of variables.

Variable	Obs	Mean	Median	S.D.	Min	Max
Marriedby15	180	3.69	1	5.62	0	30
Marriedby18	180	15.22	11.00	16.54	0	76
Vulnerability	180	0.44	0.42	0.09	0.27	0.68
Gender discrimination	158	0.35	0.36	0.19	0.04	0.83
GDP per capita	176	8.60	8.61	1.43	5.68	11.56
Extreme poverty	157	13.08	2.50	19.38	0	77.7

The econometric methodology used is Structural Equation Models (SEM) and we employ the most widely used method, i.e. maximum likelihood (ML). In regard to the relation between estimation method and sample size, following Hu & Bentler (1999), the GLS is appropriate for our regression analyses because our sample size is less than 500 observations. The results of our regressions with the GLS method are similar to the results obtained using ML which is finally our preferred method due to its richness in statistical for the goodness of fit.

4   Results

   a) OLS regression for the effect of climate change on child marriage

As a benchmark and for comparative reasons with results in the following section, Figures 1 and 2 show the results of a OLS multivariate regressions of child marriage under the age of eighteen and under the age of fifteen, respectively, with three independent variables: climate change vulnerability (vulnerability), gender inequality (genderii) and rate of extreme poverty (expovertyrate). For children married under the age of 18, Figure 1 shows a standardized coefficient of 0.29 for the effect of climate change vulnerability on child marriage, which is positive and significant at 95%. In addition, the effects of gender discrimination and the rate of extreme poverty on child marriage are also positive and significant at conventional levels. Even though, all three variables are significant, gender discrimination has the highest level of significance (99%), and it is also the one with the largest estimated coefficient, with a value of 0.44 against the values of 0.15 and 0.29 for extreme poverty and climate change vulnerability, respectively.
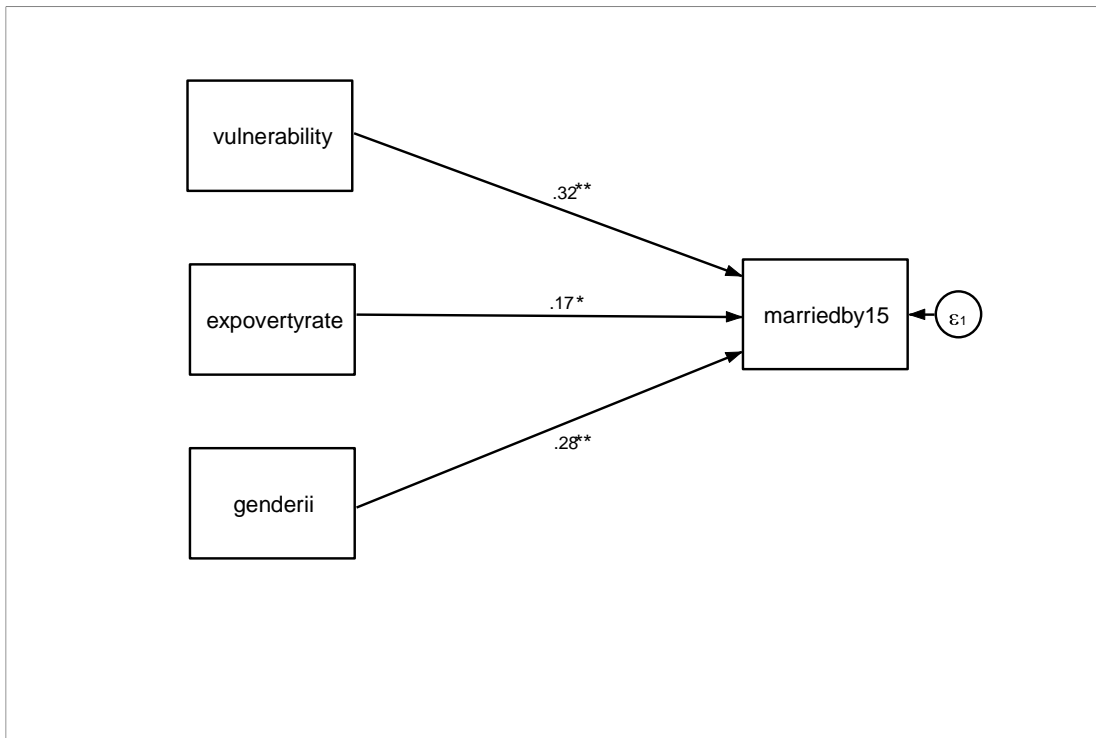
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Figure 1: OLS results for the effect of climate change on child marriage under the age of 18.
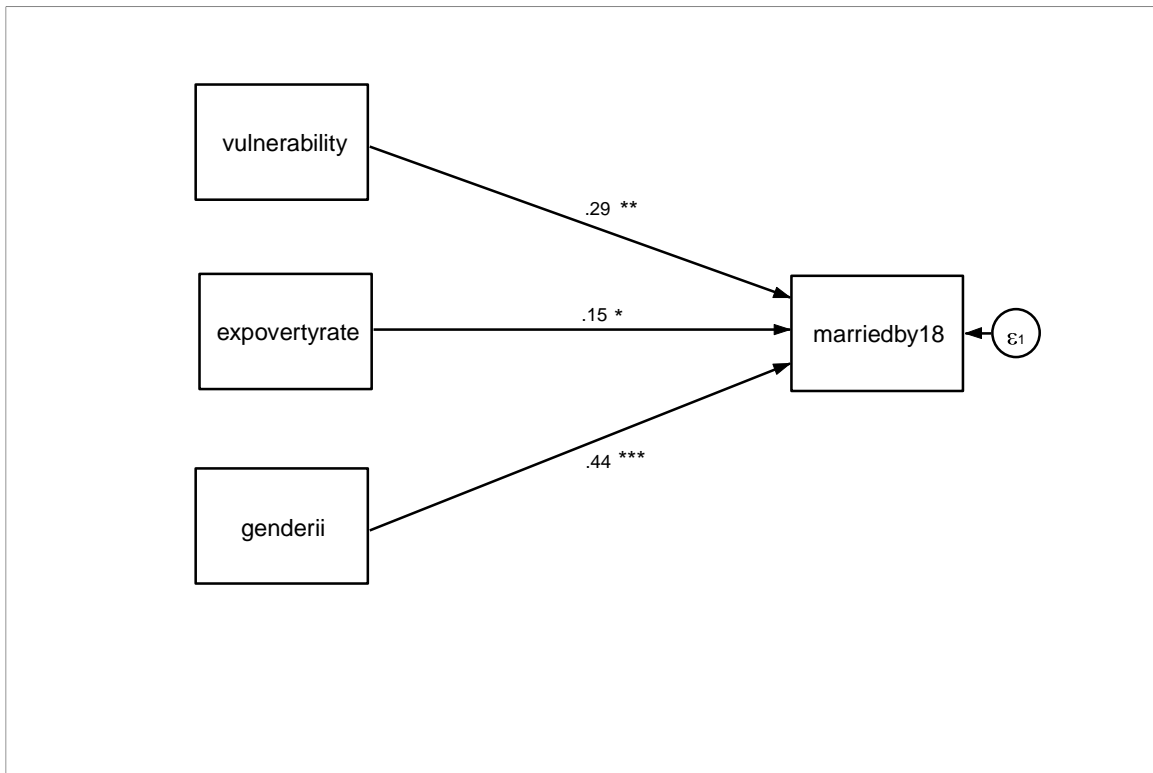
Note: *, **, *** indicate significance at the 0.05, 0.01 and 0.001 levels respectively

In regard of the determinants of child marriage for children under the age of 15, Figure 2 shows similar results to those for children married under the age of 18. In general, climate change vulnerability, extreme poverty rate and gender inequality have a high explanatory power and each one of them exhibits a positive effect on child marriage under the age of 15. Note however, that in this case, climate change vulnerability is the explanatory variable exhibiting the strongest effect on child marriage.

Figure 2: OLS results for the effect of climate change on child marriage under the age of 15

Note: *, **, *** indicate significance at the 0.05, 0.01 and 0,001 levels respectively.

b) SEM for the analysis of the effect of climate change on child marriage

Now, instead of the OLS regression model we used in the previous subsection, we employ a Structural Equation Model (SEM) to ran additional regressions in order, on the one hand, to assessing in a more precise way the effect of climate change vulnerability on child marriage, and, on the other hand, to disentangle the channels through which this effect occurs. Figure 3 and 4 show the path diagrams of how climate change in affects the percentage of marriage boys and girls under the ages of 18 and of 15 years old within our sample of 180 countries, respectively. Figure 3 shows that climate change vulnerability exhibits a direct effect on CM under 18 as well as two indirect effects. According to the figure, vulnerability has a positive and significant effect on CM, with an estimated standardized path coefficient of 0.24, which is significant at 95 %. However, as compared with the coefficient of climate change vulnerability in Figure 1, the effect is in this case is

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slightly reduced. Additionally, the figure also shows that climate change vulnerability decreases total income with a highly significant coefficient ($< 99.9 \%$ confidence level) of -0.86. This type of negative effect of climate change vulnerability on income has been previously reported by Dogru et al (2019).

Figure 3. Path diagram of the effects of Climate change on child marriage for children married under the age of 18.
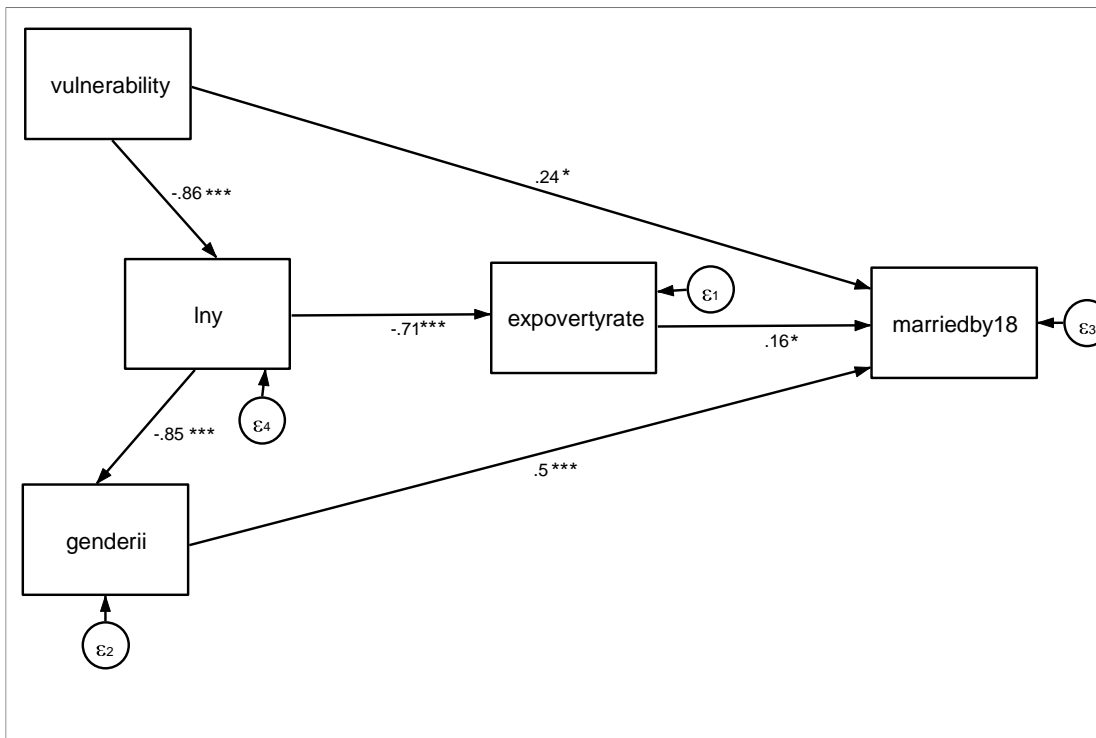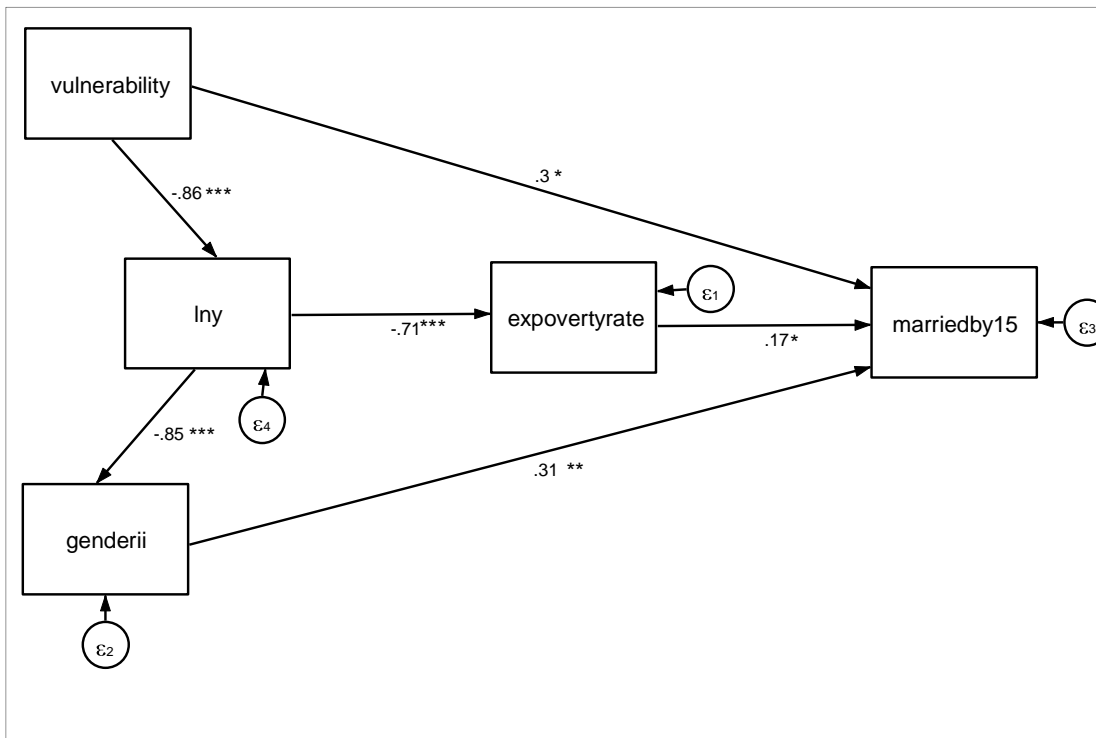

Note: *, **, *** indicate significance at the 0.05, 0.01 and 0.001 levels respectively

Moreover, Figure 3 shows that reductions in income have a positive effect on both, the rate of extreme poverty and gender inequality (with path coefficients of -0.71 and -0.85, respectively), both highly significant. This means that there are two indirect effects of climate change vulnerability on child marriage. Climate change vulnerability reduces total income and this reduction in income increases both, extreme poverty and gender inequality, and both, extreme poverty and gender inequality have a positive and significant effect on

child marriage (path coefficients 0.16 and 0.5 respectively) with the higher and more significant effect given by gender discrimination rather than extreme poverty.

Figure 4 shows the effects of climate change vulnerability on children under the age of 15. The signs of the path coefficients and the significance of the estimated coefficients are similar to those for the case married children under the age of 18. The Figure also shows that, to explaining child marriage of less than 15 years old children, the direct effect of climate change is less important than its indirect effects operating through extreme poverty or through gender inequality, and that gender inequality is again the most important variable explaining CM of this age. Thus, Figures 3 and 4 show that gender discrimination exhibits the most relevant effect on child marriage for children of 18 years of age as well as for those of 15 years of age.

Figure 4. Path diagram of the effects of Climate change on child marriage for children married under the age of 15.

Note: *, **, *** indicate significance at the 0.05, 0.01 and 0.001 levels respectively

We conclude that there are clear indications that the increase in climate change vulnerability does affect child marriage directly, increasing CM of both ages, under 18 years old and under 15 years old.   However, our estimates additionally reveal that the main effects of increases in climate change vulnerability on child marriage occur through two indirect channels. Both channels operate first, through a previous reduction in income, which, in turn, follows two different ways. In the case of one these channels, this income reduction increases extreme poverty and, in the case of the other channel, it aggravates gender inequality, with the final consequence that both of these final drivers end up being the main terminal causes of the ultimately provoked increase in child marriage. Additionally, gender discrimination shows to be relatively more important than extreme poverty in affecting child marriage.

## 5 Robustness of the results

5.1 Additional variables

We add additional control variables to our previous regressions, such as population size and two indicators for religion (one corresponding to the percentage of religious people, and the other to a dummy if the country is mostly Muslim). The results obtained are very similar to the ones of our previous model (for both types child marriage, under eighteen years old and under fifteen years old), the signs of standardized coefficients are the same and their magnitude and significances were similar. The population size variable is statistically significant and have a positive effect on child marriage (0.15 - 0.18), while none of the religion variable were significant. Finally, it is possible to observe that extreme poverty and gender discrimination are the most significant variables and gender discrimination has the higher coefficient and higher significance to explain child marriage (see Figures 5-8).

Figure 5. Path diagram of the effects of Climate change on child marriage for children married under the age of 18. Includes population and religious (as percentage of religious people) as additional variables.
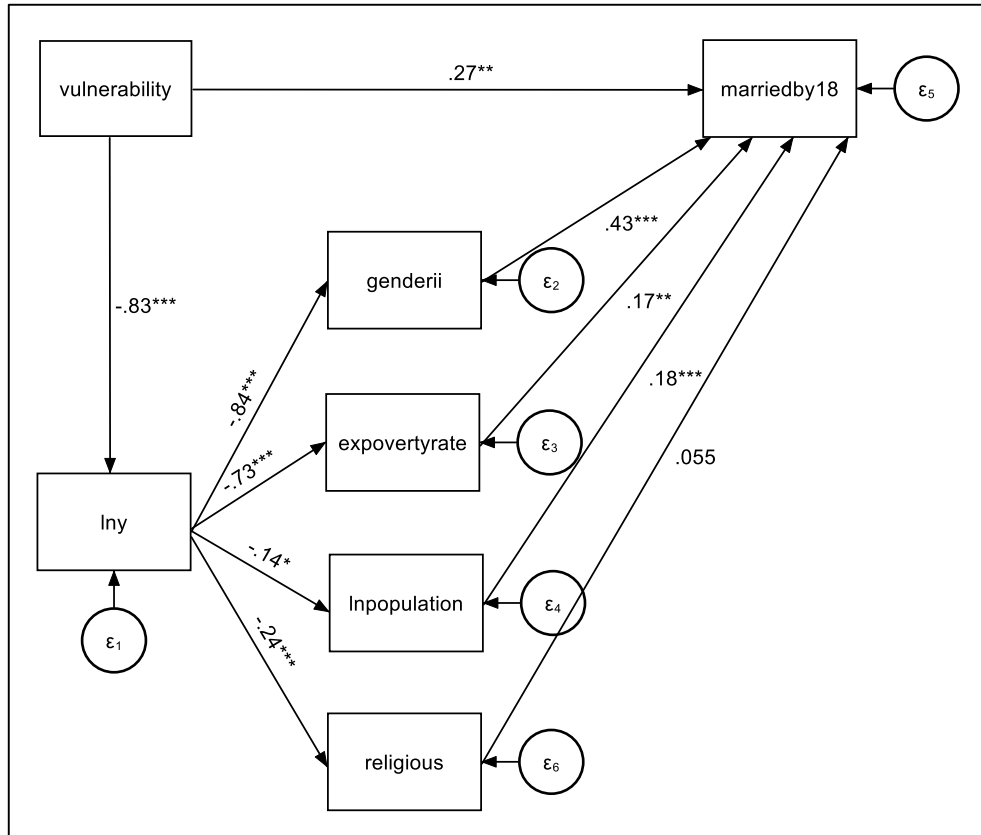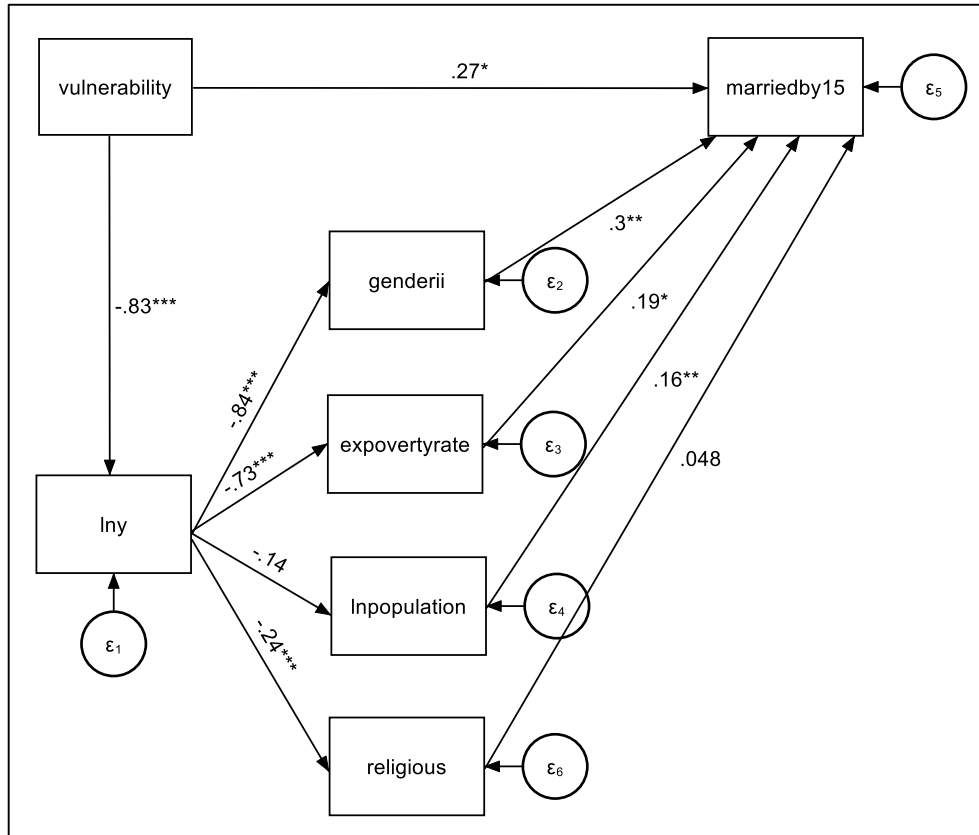

Note: *, **, *** indicate significance at the 0.05,0, 01 and 0,001 levels respectively

Figure 6. Path diagram of the effects of Climate change on child marriage for children married under the age of 18. Includes population and religious (a dummy if country is mostly Muslim) as additional variables.
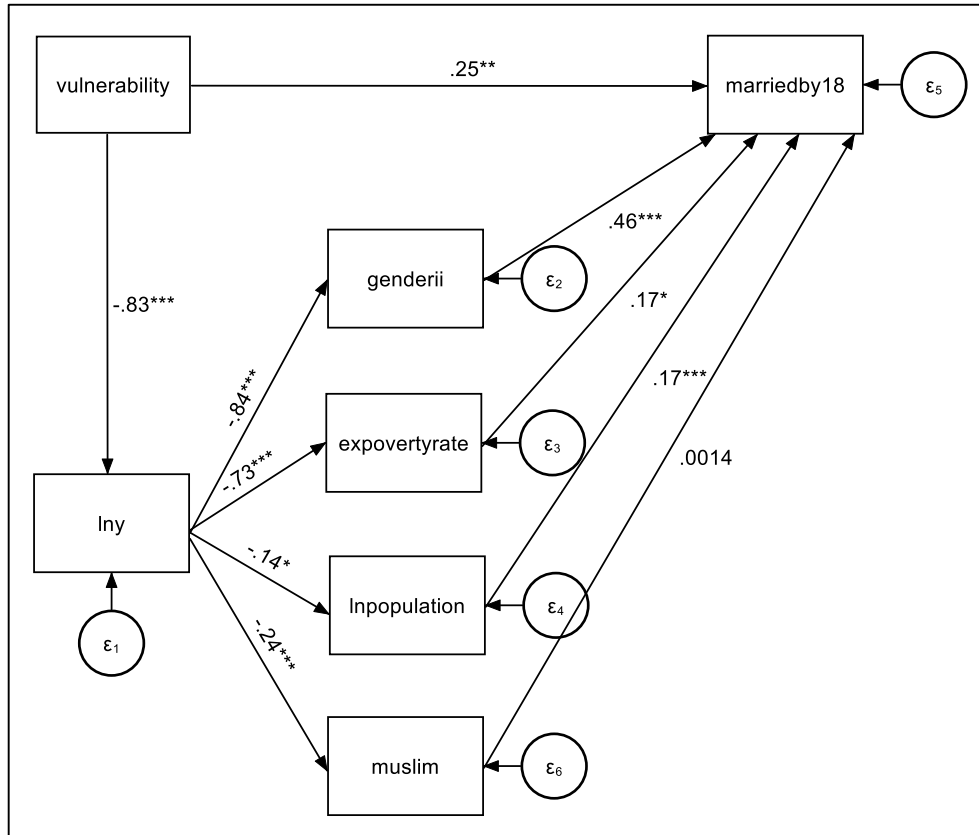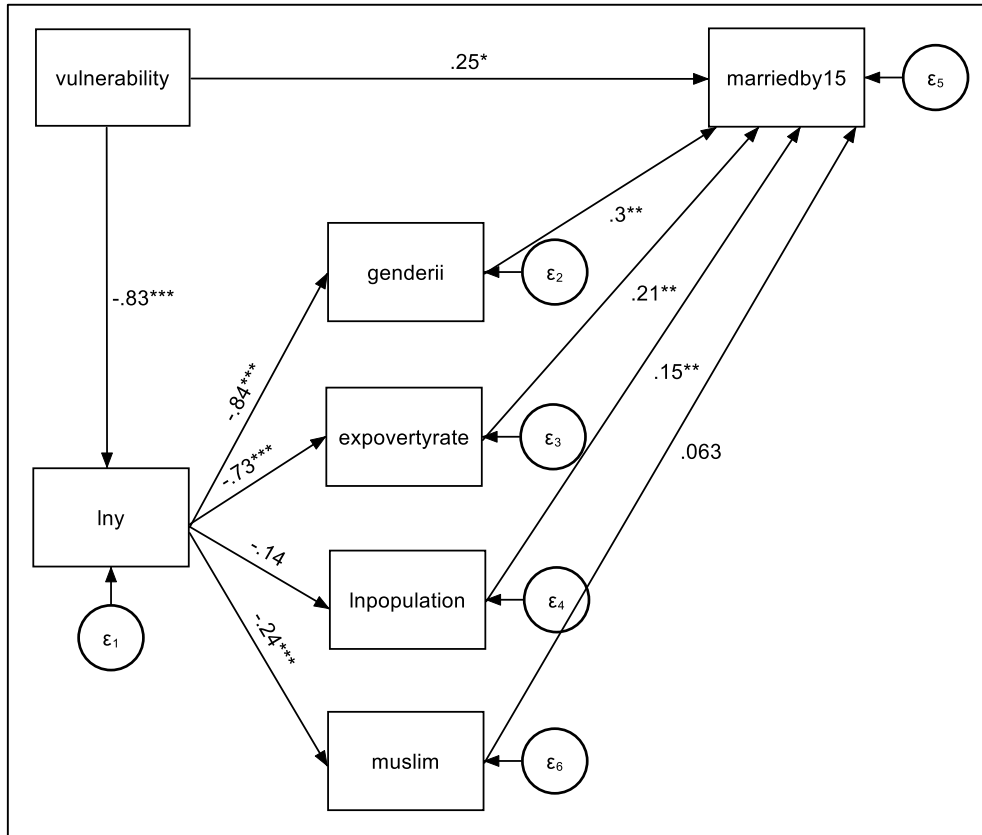

Note: *, **, *** indicate significance at the 0.05,0.01 and 0,001 levels respectively

Figure 7. Path diagram of the effects of Climate change on child marriage for children married under the age of 15. Includes population and religious (as percentage of religious people) as additional variables.

Note: *, **, *** indicate significance at the 0.05, 0.01 and 0.001 levels respectively

Figure 8. Path diagram of the effects of Climate change on child marriage for children married under the age of 15. Includes population and religious (a dummy if country is mostly Muslim) as additional variables.

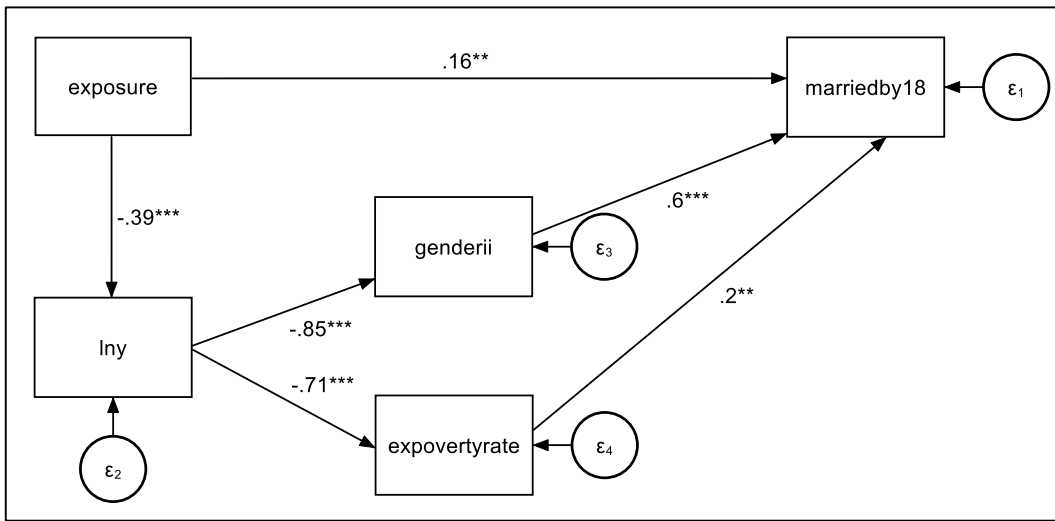Note: *, **, *** indicate significance at the 0.05, 0.01 and 0. 001 levels respectively

5.2 Exogeneity

A second potential problem of the data used here is the possibility of reverse causality between vulnerability to climate change and income. Thus, if it is income which is affecting vulnerability rather than the other way around, our specification suffers of a severe endogeneity problem. To deal with this issue we select the *exposure* component, which is one of the three components of a country´s vulnerability index. Since exposure is determined by the geophysics characteristics of a country (being an island for example), it

cannot be influenced by income and, therefore, exposure is an indicator truly exogenous. Using *exposure* instead of vulnerability in our regressions, our results remain. In particular, for marriages under the age of 18, signs of the standardized coefficients remain and the main effects are, on the one hand, a reduction of the direct impact of vulnerability to climate change (measured by the variable exposure) on child marriage and on income from 0.24 to 0.16 and from -0.86 to -0.39, respectively. On the other hand, a modest increase in the effects of the mediators (i.e. gender inequality and extreme poverty) on child marriage, from 0.50 to 0.60, and from 0.16 to 0.20, respectively.

For child marriage under the age of 15, also our results remain. Although small, the most significant changes are two. Fisrt, a reduction of the direct effect of vulnerability to climate change (measured by the variable "exposure") on child marriage and on income, from 0.30 to 0.15 and from -0.86 to -0.39, respectively. Second, an increase of the effect of gender inequality and extreme poverty on child marriage, from 0.31 to 0.46 and from 0.17 to 0.24, respectively (see Figures 9 and 10).

Figure 9. Path diagram of the effects of Climate change (measured by the variable exposure) on child marriage for children married under the age of 18.

Note: *, **, *** indicate significance at the 0.05, 0.01 and 0.001 levels respectively

Figure 10. Path diagram of the effects of Climate change (measured by the variable exposure) on child marriage for children married under the age of 15.
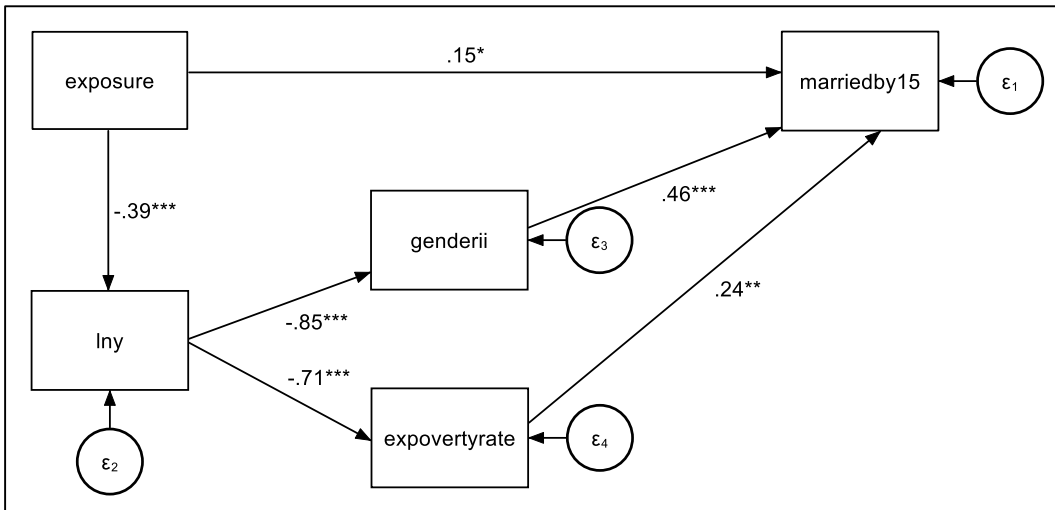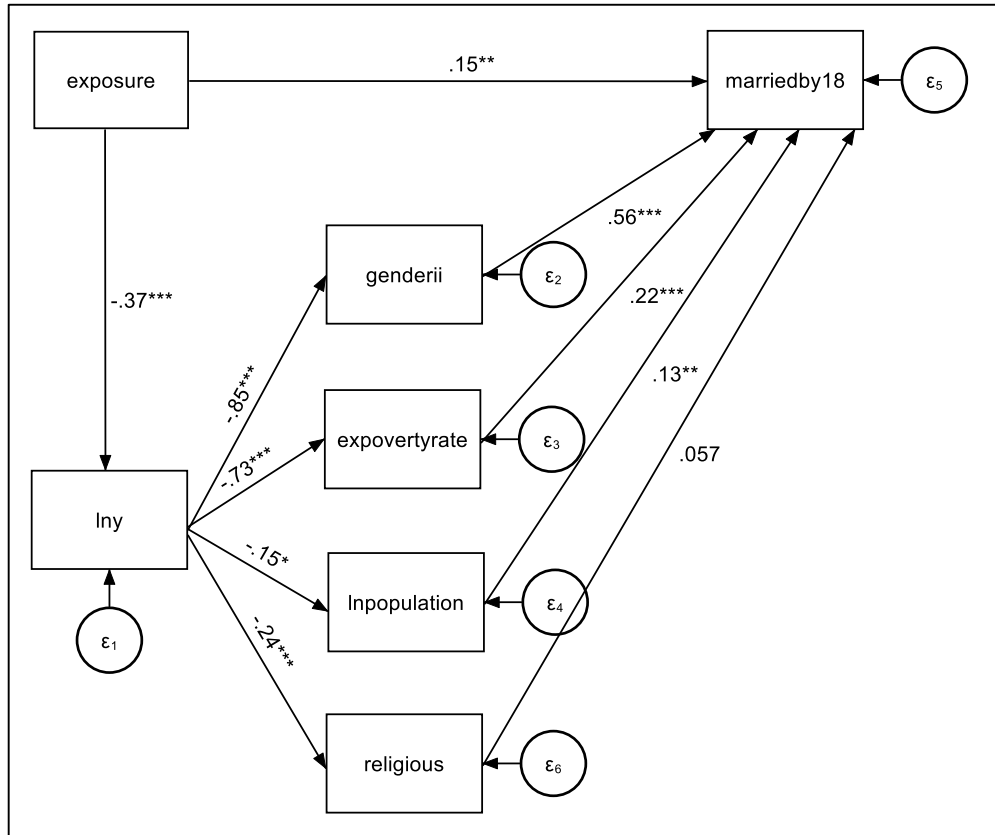

Note: *, **, *** indicate significance at the 0.05,0.01 and 0.001 levels respectively

5.3 Exogeneity and additional variables

As we stated above, the variable exposure is an indicator of the biophysics characteristics that make a country more vulnerable to climate change than others, and in this sense it is independent of the level of income, thus causality runs from vulnerability to income and not the other way around. In this section we use exposure as an independent variable together with the additional variables such as population and two indicators for religion (first; percentage of religious people and secondly; a dummy), and the results were very similar to the model without the additional variables for both marriages under the age of 18 and under the age of 15 respectively (see figures 9 and 10). Signs of the standardized coefficients remain, and their magnitude and significance are similar. Population variable is positive an statistically significant in both cases; marriages under the age of 18 and under the age of 15 in all the specifications, while the coefficients of religion are not significant (see Figures 11-14).

Figure 11. Path diagram of the effects of Climate change (measured by the variable *exposure*) on child marriage for children married under the age of 18. Includes population and religious (as percentage of religious people) as additional variables.

Note: *, **, *** indicate significance at the 0.05, 0.01 and 0.001 levels respectively

Figure 12. Path diagram of the effects of Climate change (measured by the variable *exposure*) on child marriage for children married under the age of 18. Includes population and religious (a dummy if country is mostly Muslim) as additional variables.
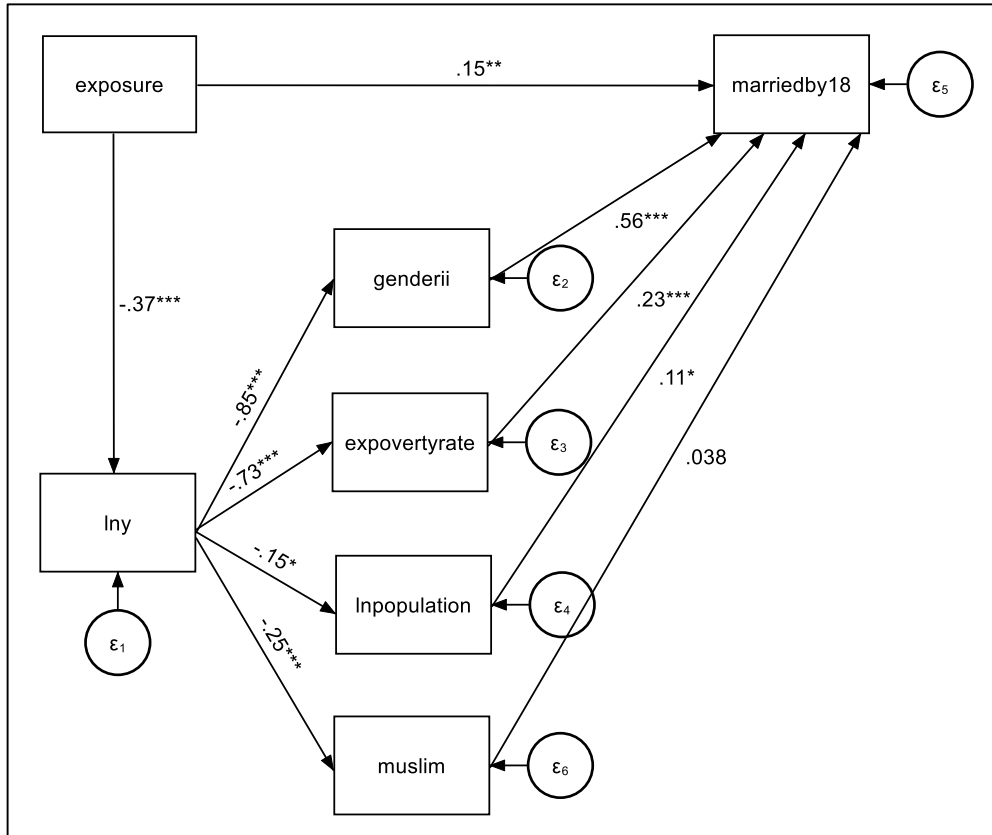
Note: *, **, *** indicate significance at the 0.05, 0.01 and 0.001 levels respectively

Figure 13. Path diagram of the effects of Climate change (measured by the variable *exposure*) on child marriage for children married under the age of 15. Includes population and religious (as percentage of religious people) as additional variables.
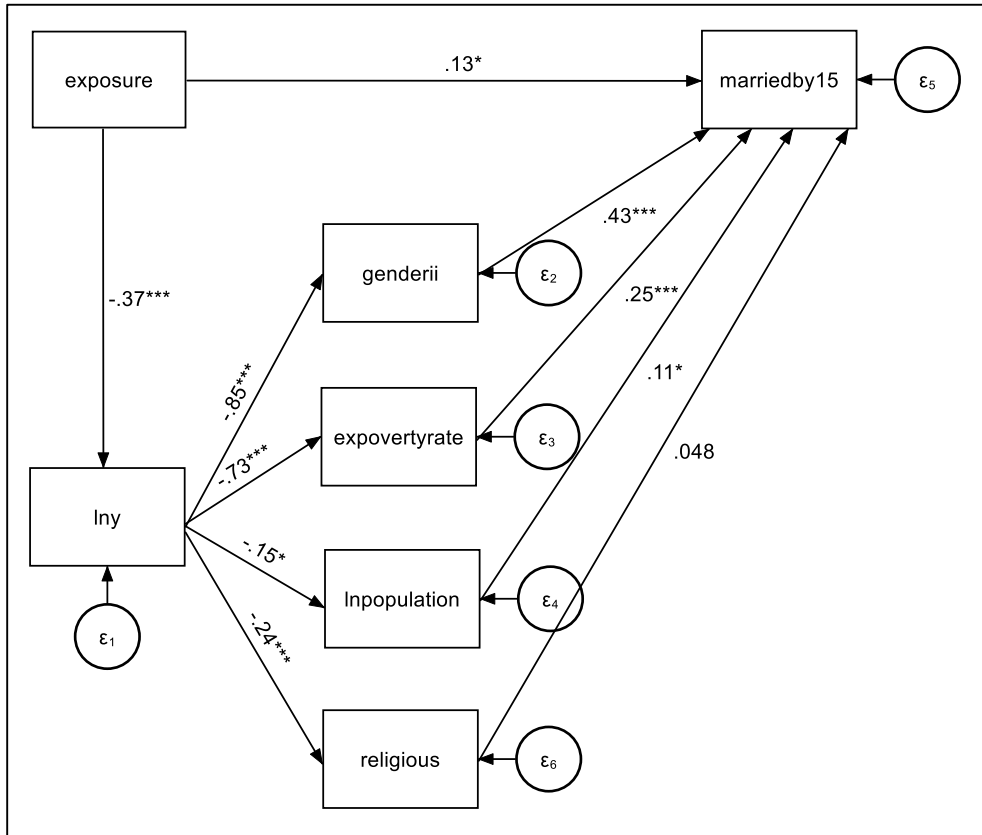

Note: *, **, *** indicate significance at the 0.05,0.01 and 0,001 levels respectively

Figure 14. Path diagram of the effects of Climate change (measured by the variable *exposure*) on child marriage for children married under the age of 18. Includes population and religious (a dummy if country is mostly Muslim) as additional variables.
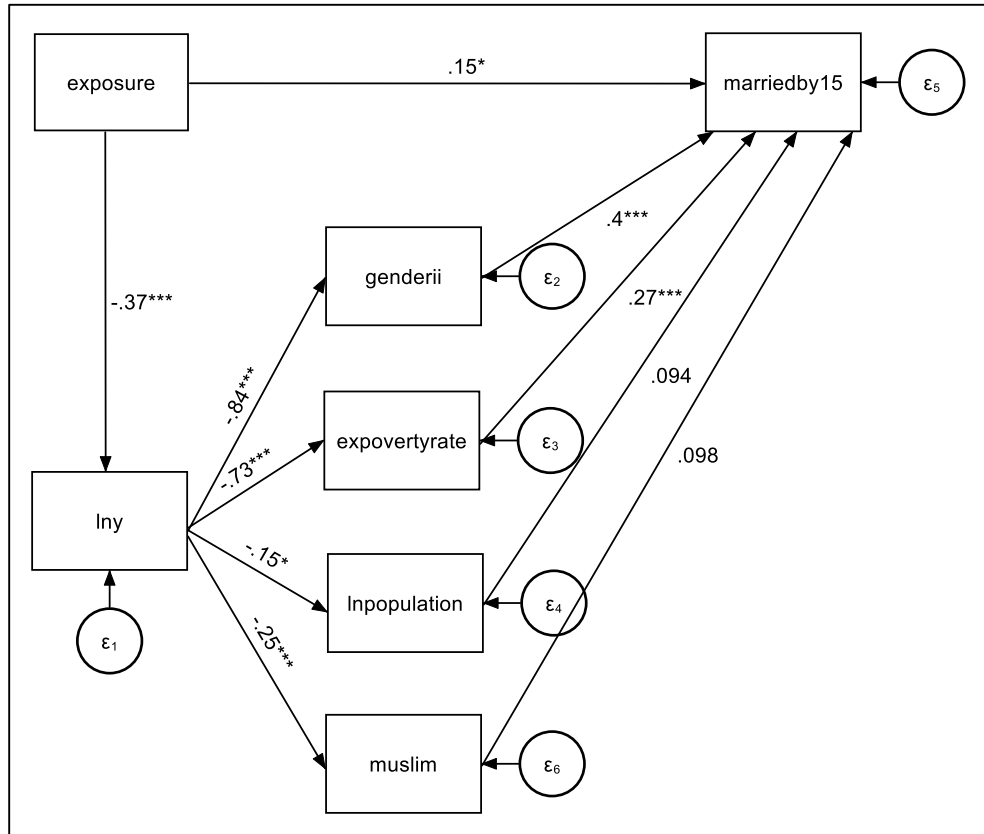

Note: *, **, *** indicate significance at the 0.05,0.01 and 0,001 levels respectively

6 Discussion and Conclusions

In this work, we have determined the impact of climate change on child marriage using cross sectional analyses with a sample of 180 countries. The effect of climate change vulnerability on child marriage have been elucidated using a SEM and controlling by extreme poverty and gender inequality.

The principal findings are related to a high correlation between climate change vulnerability and child marriage. Additionally, we found a high correlation of child

marriage with extreme poverty and gender inequality, which is in line with the results of other studies (Hotchkiss et al., 2016).

Furthermore, the effect of climate change vulnerability exhibits a double channel incidence on child marriage. On one hand, it directly affects child marriage through a channel yet to be further explored but which would operate from the fact that the more climate vulnerable countries are the more prone to climatic and natural disasters which, as the literature shows, affects the most vulnerable people, and among them, the unprotected women and children (Alston et al., 2014; Bhadwal, Sharma, Gorti, & Sen, 2019, Kumala Dewi & Dartanto, 2019; Ziegler et al., 2019, Kumala Dewi & Dartanto, 2019) .. On the other hand, if climate change is already occurring -as most of the scientific literature shows- vulnerable countries are, and will be, more affected than non-vulnerable countries. Moreover, a number of theoretical studies have hypothesized future impact of global warming (climate change) on total factor productivity (Stern 2013; Moore and Diaz 2015; Dietz and Stern 2015; Moyer et al. 2014). And recent literature has empirically estimated the negative effects of increased temperatures on total factor productivity (TFP) through its negative impacts on labor and capital productivities (Letta and Tol, 2018; Chen and Yang, 2017; Zang et al., 2017; Burke et al., 2015; Somanathan et al. 2015; Dell et al., 2012; Adhvaryu et al., 2014; Deryugina and Hsiang, 2014; Syverson, 2011; Hsiang, 2010; Aghion and Durlauf, 2005; Syverson, 2011). All these theoretical insights as well as empirical evidence clearly indicate that aggregate income is negatively affected as a country is more vulnerable to climate change, a theoretical implication and an already detected empirical fact which we have corroborated in this paper by the regressions we have performed with a sample of 180 countries, and that confirm the previous results of Dogru et al. (2019)

We have also empirically shown here that reductions of a county's aggregate income increase the country´s poverty rates (a result in line with the trickle-down theory) and increases gender discrimination probably by the mechanism of affectation on social level (Taylor et al., 2019). Finally, we have also shown that both of these variables, extreme poverty and gender discrimination, are highly correlated with child marriages of boys and girls of 18 year of age, as well as of 15 years of age.

Another interesting result is that the incidence of climate change vulnerability on child marriage is higher through the gender inequality channel than through the extreme poverty channel, a result that is in line with the empirical evidence that demonstrates the existence of the topical problem in countries independent on their income and poverty level.

Thereby we have shown here that child marriage is a complex issue, which have several dimensions of different natures and, therefore, should be addressed from different perspectives, such as the reduction of extreme poor and poor segments of the population, on the one hand, and the rise countries' general income level in developed countries, on the other hand. Moreover , at the same time, it is paramount to insist in promoting more strict laws and norms which prevent child marriage and include women in the educational system because of the existing evidence relating child marriage with the access to education for women ((Hotchkiss et al., 2016; Male & Wodon, 2018; Subramanian, 2008; Wodon, 2018). Furthermore, the impulse of public and private policies against gender inequality and inequity is crucial to achieve a cultural change in terms of the role of women and the elimination of gender discrimination. Finally, if the definition of vulnerability to climate change is restricted to geophysical characteristics of a country (being an island for example), all our previous results remain, clearly indicating that there is no reverse causality and therefore our results are free of endogeneity problems.

Summing up, as we mention before, the underlying causes of child marriage are difficult to disentangle, even though there is some understanding about their consequences as often being reported by the media. With the results of our econometric estimations presented here, we have contributed to uncover climate change as a an statistically significant direct cause of child marriage; and to clearly identify and characterize the two transmission channels through which climate change indirectly determines child marriage: first, climate change in most vulnerable countries indirectly increases child marriages, more likely because climatic and natural events disproportionately affects the incomes of most vulnerable people, and among them, especially children and girls, who, due to cultural discriminatory behaviours are pushed into marriage; second, climate change in vulnerable countries reduces total income which, in turn, increases the rate of extreme poverty which is a major end driver of child marriage.

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