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The role of social inequalities for the vulnerability to climate related extreme weather events

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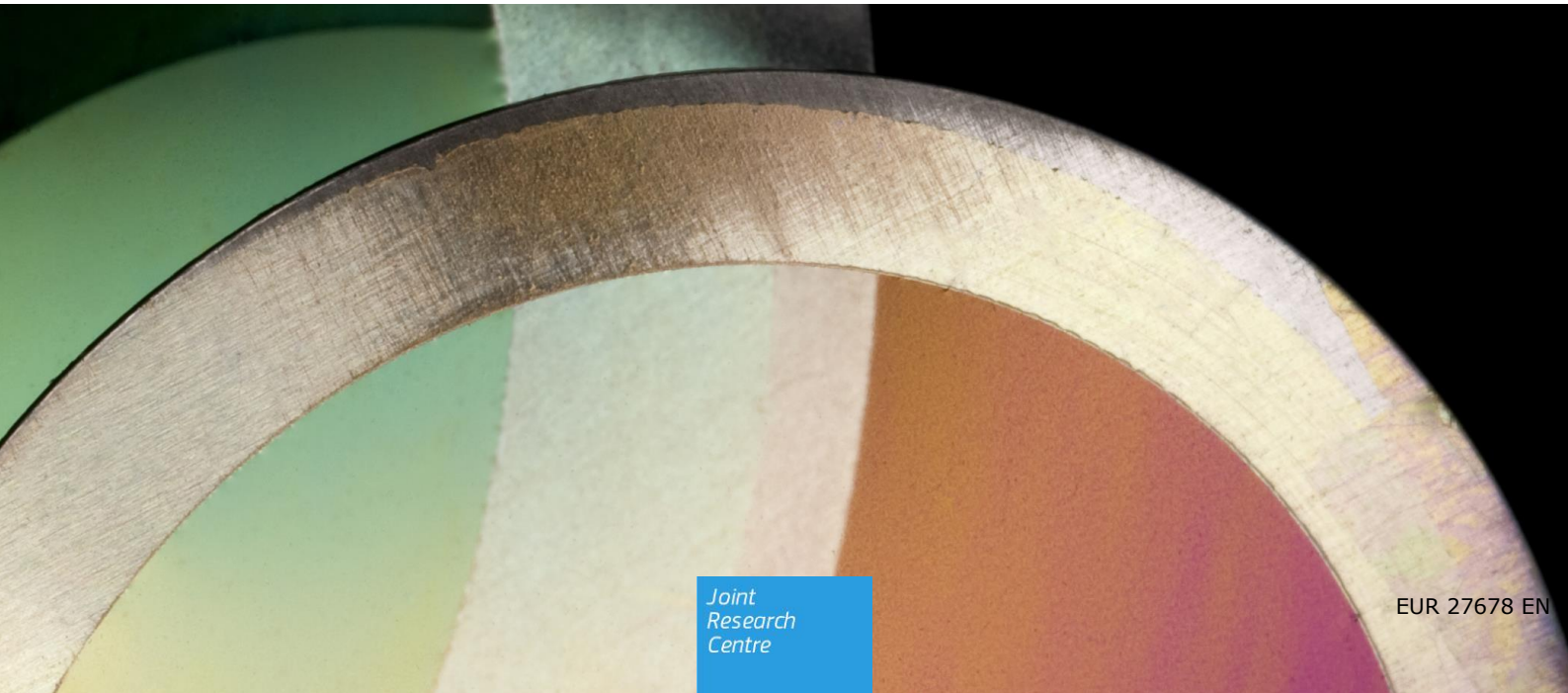

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Abstract

This report analyses the differential impact of extreme weather events in the presence of social inequalities. It hypothesizes that social inequalities affect vulnerability and resilience through its impact on the capacity to cope and empirically analyses the differential impact of extreme weather events in the presence of social inequalities. To sidestep the methodological difficulties of quantifying vulnerability or resilience, the relation between different inequalities and disaster fatalities are established. The death toll from a given disaster is a function of hazard, exposure and vulnerability and everything else constant, more casualties imply higher levels of vulnerability. The results establish that countries with more equality in gender issues and the distribution of incomes on average face lower fatalities when climate related extreme weather events strike. While this holds for all measures of the income distribution employed, for gender equality this relation can be established for some but not for all proxies used to measure the phenomenon. The relation is valid and robust for female to male enrolment ratios in secondary education, female labour force participation and to some degree for female members of parliament. A statistical relation between more gender and/or income equality associated with a reduction in the probability of high numbers of disaster fatalities provides indirect evidence for a reduction in vulnerability. But what is the underlying mechanism, i.e. why should inequality increase vulnerability or decrease system resilience? The report proposes a sketch of a theory as input for future research, relating inequality to trust and cooperation as important building blocks for societies' capacity to cope and resilience.

1. Introduction

Anthropogenic climate change (CC) contributes to increases in mean temperatures and weather variability. Changing precipitation patterns and more frequent and more severe extreme weather events are the result. The impact of a given hazard on exposed entities depends on their vulnerability and resilience (IPCC 2012, 2014). We hypothesize that social inequalities affect vulnerability and resilience through its impact on the capacity to cope and empirically analyse the differential impact of extreme weather events in the presence of social inequalities. To sidestep the methodological difficulties of quantifying vulnerability or resilience, the relation between different inequalities and disaster fatalities are established. The death toll from a given disaster is a function of hazard, exposure and vulnerability and everything else constant, more casualties imply higher levels of vulnerability.

The results establish that countries with more equality in gender issues and the distribution of incomes on average face lower fatalities when climate related extreme weather events strike. While this holds for all measures of the income distribution employed, for gender equality this relation can be established for some but not for all proxies used to measure the phenomenon. The relation is valid and robust for female to male enrolment ratios in secondary education, female labour force participation and to some degree for female members of parliament

There is a considerable and growing literature on the economic impacts of natural disasters and extreme weather events on the macro- as well as on the microeconomic level. On the macro level a large number of studies focus on the effect of natural disasters on growth and the relation between economic development and the economic costs of respective disasters. Some studies restrict their attention to specific disaster-types, others evaluate all types of disasters. On the micro level the perspective is mostly restricted to specific disaster types or individual disasters and their impacts on households with an analysis of individual determinants of vulnerability and individual adaptive strategies employed.

There are a number of reviews that allow for a quick overview over the ongoing debates: Lazzaroni and van Bergeijk (2014) give an overview over different themes and provide a meta-analysis of the macro-economic literature on economic costs of natural disasters. Kousky (2014) discusses the literature with an emphasis on adaptation, restricting her review on publications that consider economic impacts of hydro-meteorological disasters. Mochizuki et al. (2014) provide an overview over the contributions and problems associated with the debate around disaster losses and development.

Cavello and Noy (2010) provide a review of the first generation of this literature. In general, natural disasters and extreme weather events are found to have a negative effect on short and long-term growth. However, for some sectors and some types of disaster events there is a positive association (e.g. floods sometimes have a positive effect on agriculture). Also see Felbermayer and Gröschl (2014), Cavallo et al. (2013), Loayza et al. (2012), Fomby et al. (2013), Raddatz (2009), Noy (2009), Klomp and Valckx (2014) and Hsiang and Jina (2014).

Dell et al. (2014) deliver a comprehensive review over the whole "New Climate Economy Literature". After summing up the related methodological issues, they categorize the economic literature on weather and climate along the dependent variables considered: aggregate output, agriculture, labour productivity, industrial and service-output, health and mortality, energy, conflict and political stability, crime, trade and finally, innovation.

Climate change effects on poverty also receive considerable attention in the literature. A literature review is provided by Leichenko and Silva (2014). Climate change is seen to affect poverty by influencing prices, assets, opportunities and productivity and is generally understood to put additional strains on the task of poverty eradication (or

reduction). However, efforts to fight poverty are complementary to efforts of adaptation and mitigation of climate change (Hallegatte et al. 2014, Skoufias 2012).

A few contributions look at the effect of natural disasters and extreme weather events on the distribution of incomes. Miljkovic and Miljkovic (2014) show that on a state level in the U.S. more damages from hurricanes are associated with a stronger concentration of incomes. Silva et al. (2015) show that extreme weather events in Mozambique tend to exacerbate existing income inequalities and social divisions in most, but not all exposed regions.

Other publications differentiate disaster impacts along socio-economic and gender-lines. Neumayer and Plümper (2007) show that the decrease of life expectancy induced by natural disasters is higher for women than for men. A gendered mortality effect against infant girls in the aftermath of typhoons in the Philippines is discovered by Anttila-Huges and Hsiang (2013). Similarly, for Burkina Faso and all sub-Saharan Africa it is shown that nutrition and health outcomes for girls are more negatively affected by droughts than for boys (Araujo Bonjean et al. 2012, Flatø and Kotsadam 2014). Related is the literature that differentiates outcomes of disasters along socio-economic status (Leichenko and Silva 2014, Bennett and Friel 2014).

The recognition that social categories like status and gender co-determine the impacts of negative shocks, justifies and supports the vulnerability perspective which has been embraced by the climate change community early on.

In the literature it is well established that vulnerability and adaptation depend on the level of development and institutional quality both on the macro and the micro level (e.g. Dow et al. 2006, Wheeler 2011, Lazzaroni and van Bergeijk 2014). Increasingly there is also recognition of the importance of the distribution of rights and resources and the detrimental impact of social inequalities. However, the empirical literature which quantifies the determinants of direct and indirect costs of disasters and extreme weather events mostly ignores those aspects of distribution. Exception are Anbarci et al. (2005) and Kuhn (2005) which show that the death toll from earthquakes and natural disasters are positively and significant correlated with the Gini coefficient of the income distribution.

It is argued that social inequalities are negatively related to social cohesion and trust which are prerequisites for cooperation and the provision of public goods which are necessary for a society's capacity to cope. Anbarci et al. (2005) provide a theoretical model where cooperation is necessary for the universal provision of adaptive measures with public goods character. If income inequality exceeds some threshold level, the rich will no longer participate in the provision of the public good and will only provide private adaptation for themselves. Germano and Demetrius (2014) argue, based on the recent theoretical concept of evolutionary entropy, that societies which are more equal are also more resilient. The underlying mechanism is again attributed to a higher level of cooperation among agents in such a society with flat hierarchies.

We test two main hypothesis: (1) Ceteris paribus the impact of a given hazard is higher in countries with more unequal gender rights. (2) Ceteris paribus the impact of a given hazard is higher in countries with a more concentrated distribution of income. The impact is measured by disaster fatalities.

The next section provides a detailed discussion of the data employed in the analysis and its shortcomings. In Section 3 the empirical strategy is laid out and the appropriate methodological approach is discussed. In the fourth section a detailed description of the variables used, their statistical properties and their distribution over time and space is provided. Section 5 presents the results. In Section 6 a multiplicity of robustness checks are discussed. Section 7 concludes by summarizing the results, pointing out caveats and discussing avenues for future research.

2. The Data

In order to tackle the influence of social inequalities on fatality rates associated with extreme weather events we take a macroeconomic perspective with a given country in a given year as unit of observation. The macro-perspective is chosen for a number of reasons: disaster fatalities and disaster occurrence is mostly not available on a subnational level, the distribution of gender rights and incomes are structural variables which are often not available on a subnational level. In the following we discuss the variables of interest, their underlying data sources and caveats to be considered with respective data.

2.1 Measuring climate related disasters

To capture extreme weather events we use the EM-DAT disaster data from Centre for Research on the Epidemiology of Disasters (CRED) which records disasters going back to 1900. A disaster is recorded if one or more of the following conditions hold: ten or more people are reported killed, a hundred or more people are reported affected, a state of emergency was declared and/or international assistance was called for.

We restrict our attention to four types of extreme weather events: droughts, floods, storms and extreme temperature events. These types of events are reasonable closely linked to the climate and are expected to become more frequent with increases in weather variability as likely induced by climate change (IPCC 2012).

EM-DAT records the date and country when and where a disaster strikes, the resulting dead and missing persons, people homeless and affected and a damage estimate. The total number of fatalities (*totdeath_4d*)[1] from the four disasters analysed will be our dependent variable. Descriptive statistics are relegated to section 4. A multiplicity of possible reporting biases underlying this data and the related literature will be discussed in subsection 2.4 on data problems below.

2.2 Measuring social inequalities

While social inequalities can embrace a multiplicity of dimension we restrict our attention to two dimensions of inequality (Blackburn 2008): the concentration of incomes and the distribution of gender rights which now will be discussed in turn.

2.2.1 Income Inequality

To measure the degree of income inequality we use the Gini coefficient of market (*gini_market*) and after tax and transfers income (*gini_net*). The measurement of the distribution of incomes presupposes the definition of an income concept and the choice of an appropriate concentration measure. Differences in the measurement of individual and household incomes before and after tax and transfers make a comparison of income measures and more so of the derived concentration measures problematic (Atkinson and Brandolini 2001). For some countries and some years there are highly standardized income measures available and full comparability of concentration measures is ensured.[2] This however restricts the sample size to a few countries and a short time span. Accordingly there is a trade-off between sample size and comparability. The Standardized World Income Inequality Database (SWIID) is constructed with this trade-off in mind and aims to maximize the sample size while accounting for the problems of

[1] Variables are generally set in italics.
[2] See the LIS project at http://www.lisdatacenter.org/

comparability, making efforts to minimizing them (Solt 2009, 2014). The SWIID provides the Gini coefficient of market and net incomes for a large sample of country years (sample details and descriptive statistics are provided in Section 4). In addition a second estimate of the Gini coefficient as provided by the World Bank will be used. The Gini coefficient of incomes is strongly influenced by middle incomes and gives less emphasis on very high and low incomes. The index does not specify where in the income distribution the inequality occurs. Accordingly, two very different income distributions could result in the same Gini coefficient. The Gini is still the most widely used measure of income concentration.

2.2.1 Gender Inequality

Gender inequality[3] is the second dimension of social inequality we consider. It is a concept that poses considerable challenges to operationalization and measurement. Not only is it difficult to define what gender equality is, but the concept of gender itself is complex and multifaceted. It is a contested concept[4] and its meaning is highly context dependent[5]. Reducing the gender concept to the simple dichotomy of men and women, it is still necessary to define what constitutes gender equality. Since gender equality might be domain dependent it is reasonable to employ a number of different measures across domains. The degree in which gender equality in education, labour markets or political participation constitute overall gender equality is up to debate. Blackburn et al. (2000) for example show, how two measures of gender equality, occupational gender segregation and the UN development measure of gender equality paint contrary pictures. Societies with more occupation gender segregation tend to have higher gender equality scores as measures by the UN. These problems should be kept in mind in the following analysis.

A first step to capture gender inequalities is to look for gender discrimination in the formal legal rules of a country. Albeit today women are equal to men in the legal code of most countries, considerable inequalities persist in its application. The CIRI human rights data set (Cingranelli et al. 2014) provides measures of female political rights, female economic rights and female social rights.[6] The ordinal variables are coded ranging from 0-3. A score of 0 indicates that women are discriminated by formal legal rules, score 1 indicates that respective rights are guaranteed by law but severely inhibited in practice. In countries with a score of 2 guaranteed legal rights for women are moderately inhibited in practice and a score of 3 indicates that respective women rights are guaranteed by law and in practice. The set of political, economic and social rights covered by the variables and their coding as provided in the detailed codebook are presented in Table A1 in the appendix.

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[3] Gender is a contested concept. Increasingly the binary definition of male/female is rejected and gender perceived as a continuum where all combinations of biological sex and socially constructed gender co-exist. Gender equality in the present report refers to equal rights of women as compared to men and as such implicitly assumes the traditional, binary concept of gender. We acknowledge that gender equality needs to account for non-traditional gender identities but ignore these aspect for simplicity (and data availability).

[4] For problems with the measurement of economic gender inequality see e.g. Ponthieux and Meurs (2015).

[5] "Gender, rather than being an intractable characteristic of individuals, is dynamic and the roles, responsibilities, power relationships, and resources associated with being a man or a woman can vary significantly depending on the situation, even for the same individual." (USAID, 2015).

[6] The variable on female social rights has been discontinued as of 2005/2007.

Since there might be some problems with the coding of the CIRI variables, as will be discussed in more detail in subsection 2.4 on data problems below, we also consider a couple of macroeconomic measures of female participation in education and the labour market. Those variables are derived from the World Development Indicators (WDI, World Bank 2015) and the Quality of Governance (QoG) Dataset (Teorell et al. 2015).

More specifically, the ratio of female to male enrolment rates in primary (*ratio_enroll_primary*), secondary (*ratio_enroll_second*) and tertiary education (*ratio_enroll_tertiary*), as well as the gender ratio in primary and secondary education together (*ratio_prim_sec*) are used as education based indicators of gender equality. The share of the female labour force in the total labour force (*female_lfp*) is used as indicator of gender equality in the labour market. The finale indicator of gender equality in political participation is the share of female members of parliament (*female_mp*).

Dreher et al. (2015) analyse if the allocation of foreign aid is influenced by gender inequality in recipient countries. They distinguish four types of gender inequality (gender inequality in economic and social rights, in survival, in education and in empowerment) and use similar proxies as we do. We omit gender inequality in survival since survival (i.e. the mortality rate) might be influenced by disaster fatalities, our dependent variable, thus creating endogeneity. In fact, Neumayer and Plümper (2007) show that conditional on women's socioeconomic status, natural disasters reduce the life expectancy of women more than that of men. This is interpreted as evidence "that it is socially constructed gender-specific vulnerability of females built into everyday socioeconomic patters" (Neumayer and Plümper 2007) which lead to higher female mortality.

2.3 Control Variables

To minimize the problems of unobserved heterogeneity a multiplicity of country characteristics and co-determinants of vulnerability are included in the regressions. The data sources are the World Development Indicators (WDI, World Bank 2015) and the Quality of Governance (QoG) Dataset (Teorell et al. 2015). Individual controls employed will be introduced in the next section when the estimation strategy is explained. A detailed description of respective variables is then provided in Subsection 4.4.

2.4 Problems with the data

Empirical exercises are often considered messy because available data is incomplete, available variables only capture part of what the analyst wants to look at and because there is little guidance as to what is the appropriate specification. In the present subsection we discuss some of the problems with the data we are using. Specifically we will look at biased disaster recording in the EM-DAT data and coding problems in the measures of gender inequality from the CIRI human rights data.

2.4.1 EM-DAT disaster data base

The EM-DAT is still the most comprehensive, freely available and most widely used database of disaster events available.[7] Accordingly, we use this dataset to assure comparability of our results with the literature and to better understand the conditionality of published results.

The entries to the EM-DAT are gathered from various sources like government and non-government institutions, insurances and media outlets (Cavallo and Noy 2011). Accordingly, there are measurement errors "due to compilation errors and harmonization

[7] Tschoegl (2006) provides an analytical review of available data sets.

from various data sources" (Loayza et al. 2012). In addition there are systematic biases in the recording of disasters for a multiplicity of reasons:

> "One general concern is that reporting (and misreporting) of disasters varies systematically across time, levels of income, and political regimes. Reporting of small disasters is probably more complete in later years and in more developed countries" (Strömberg 2007, 201).

Biased reporting of disaster occurrences can result e.g. from conscious over- or underreporting of governments, from differential media coverage, differential insurance coverage or limited administrative capabilities in developing countries, to name but a few (Strömberg 2007, Raschky 2008). The resulting problem of measurement error in the data is even bigger when it comes to the number of disaster fatalities, people affected and the value of economic damages.

In a recent contribution Felbermayr and Gröschl (2014) introduce a novel dataset (GeoMet) compiled from primary sources, i.e. meteorological and geological data. A disaster at a given geographic point (grid-cell) is derived from meteorological or geological indicators at that point that exceed (or undercut) some benchmark value. For example, the Richter scale is used to identify earthquakes and data on precipitation anomalies for the identification of droughts and floods. The authors compare their data with EM-DAT and find no correlation for earthquakes but considerable correlation for storms and hurricanes. However, there is a less pronounced time trend for storms in the GeoMet data. It is also shown that per-capita GDP is an important predictor for reporting earthquakes, storms and floods in EM-DAT. This creates a problem of endogeneity in studies that aim to determine the growth effect of natural disasters: the level or change of GDP per capita should be explained by the occurrence or strength of disasters the reporting of which in turn depend on the level of GDP per capita. For these type of studies the GeoMet has some great advantages. However, there are also problems with this type of disaster data. First, the dataset does not report natural disaster but natural hazards. Neither a tornado over an empty sea nor an earthquake in an empty desert are considered disasters. For a hazard to become a disaster, vulnerable entities have to be exposed to the hazard. Second, the primary data used to construct GeoMet are measured by a grid of globally distributed weather and geo-sensors. Especially the density of weather stations is also correlated with GDP per capita. A low density of weather stations increases the necessity for interpolation and simulation of meteorological variables and increases the uncertainty associated with these. A similar, albeit less grave problem of endogeneity as for EM-DAT might result (Auffhammer et al. 2013).

2.4.2 CIRI human rights data base

The CIRI human rights data project provides "standards-based quantitative information on government respect for human rights in 202 countries, annually from 1981-2011" (Cingranelli et al. 2014). It contains three variables related to gender equality: women political (*wopol*), social (*wosoc*) and economic rights (*wecon*). They are coded based on information derived from the U.S. State Department Country Reports on Human Rights Practices (USSD). Critics state that the report is or can be subject to foreign policy political interests (e.g. The Guardian 2015). Also, albeit the CIRI project is very careful to provide clear coding rules and guidance in the case of missing or ambivalent information, some idiosyncratic leeway in the coding-decision remain. Lastly, as will be seen in Section 4 where the data is described in some detail, these measures do not exhibit a lot of variation making it difficult to estimate their effect.

The CIRI variables on women rights should be complemented with further measures of gender equality not only for reasons of data reliability, but also because of the multifaceted aspect of gender equality which cannot be captured by a focus on legal rules and their enactment alone.

3. Methodology

This section first discusses the assumptions taken when using the EM-DAT data. The characteristics of the dependent variable provides some guidance for the choice of the appropriate estimation method which is discussed in the next subsection. Finally the empirical strategy will be detailed.

3.1 Using EM-DAT disaster data

The EM-DAT data records the year and the country in which a disasters struck. We assume that in those years and countries which do not have an entry in the data no disaster has happened. Since disasters are still rare events, this creates a lot of zero entries. In order to better isolate the impact of disasters we restrict the sample and exclude all countries that do not experience any disaster in the observation period 1980-2014.[8]

In the main analysis two variables from EM-DAT are employed: total fatalities per disaster-type and count of occurrences per disaster-type. As mentioned earlier we restrict our attention to droughts, floods, extreme temperature events and storms and accordingly sum up the number of total fatalities from all these disasters, resulting in our dependent variable: sum of total deaths from the four analysed disaster types (*totdeath_4d*). To understand which estimation method is appropriate for respective data the descriptive statistics are shown in Table 1 and Table 2.[9]

Table 1. Disaster fatalities by occurrence of droughts and extreme temperature events.

Occurrence Droughts			
	Mean	Variance	N
0	0	0	6722
1	1226.88	2.58E+08	474
2	0	0	12
3	0	0	2
Total	80.66	1.70E+07	7210

Occurrence Extreme temp.			
	Mean	Variance	N
0	0	0	6806
1	282.51	3221307.00	341
2	242.28	230188.40	54
3	6361.33	3.43E+08	9
Total	23.12	5.89E+05	7210

It is obvious that for all disaster types there are a lot of zero observations, i.e. country-years without disasters and associated fatalities. Data with a large share of zero observations is called zero inflated data. Further, it can be seen that the variance of disaster fatalities by far exceeds the mean for almost all counts of disaster occurrence. This phenomenon is called over-dispersion. To explain this type of data the literature proposes a zero-inflated negative binomial count model (Green 2007, Kuhn 2005).

[8] Qualitatively results remain unchanged by this sample restriction.
[9] A more detailed look at the data is provided in Section 4.

Table 2. Disaster fatalities by occurrence of floods and storms.

Occurrence Floods			
	Mean	Variance	N
0	0	0	5143
1	34.99	19604.74	1251
2	82.30	69469.37	437
3	331.73	5429435	168
4	223.08	288576	83
5	617.76	1652264	38
6	487.74	395352.90	38
7	371.88	112506.50	16
8	484.87	252943.30	15
9	449.67	47831.47	6
10	667.50	669324.50	2
11	309	144722	2
12	588	211548	3
13	512		1
14	326	193442	2
15	122		1
16	2051		1
17	1661.50	437112.50	2
18	430		1
Total	30.89	156958.80	7210

Occurrence Storms			
	mean	variance	N
0	0	0	5831
1	42.73	266233.50	865
2	647.60	80500000	240
3	416.60	3755881	91
4	353.31	430863.20	49
5	308.97	194299.20	34
6	462.16	1421275	25
7	354.08	163645.20	12
8	1236.15	3897454	13
9	444.70	341120.20	10
10	438.14	374521.10	7
11	511.14	141305.80	7
12	537.25	689294.30	4
13	190.50	5940.50	2
14	672	188304	4
15	215.83	5597.37	6
16	167.50	7080.50	2
17	84.50	12.50	2
18	27		1
19	190		1
20	247	3872	2
23	180		1
27	95		1
Total	42.87	2785617	7210

3.2 The zero inflated negative binomial count model (ZINB)

For zero inflated count data the zero inflated Poisson model (ZIP) and the zero inflated negative binomial count model (ZINB), as established, e.g. by Heilbron (1994), Lambert (1992) and Greene (1994) can be appropriate approaches.[10] These are two step models with "an equation for 'participation' and a model for the event count" (Green 2007, p. 137), linked by an observation mechanism.

The ZINB model maximizes the log likelihood function $\ln L$ as defined by:

$$m = 1/\alpha$$

$$p_j = 1/[1 + \alpha \exp(\mathbf{x}_j \beta)]$$

[10] Green (2007) provides an extensive overview over the whole family of count models.

$$\ln L = \sum_{j \in S} \ln\left[F(\mathbf{z}_j\gamma) + \{1 - F(\mathbf{z}_j\gamma)\}p_j^m\right] +$$

$$+ \sum_{j \notin S} \left[\ln\{1 - F(\mathbf{z}_j\gamma)\} + \ln\Gamma(m + y_j) - \ln\Gamma(y_j + 1) - \ln\Gamma(m) + m\ln p_j + y_j \ln(1 - p_j)\right]$$

F is the inverse of the logit link, Γ is the gamma distribution and S is the set of observations with outcome zero, i.e. country-year observations with no disaster fatalities (StataCorp 2015). The probability that a country in a given year has zero count for disaster fatalities is estimated with a logit model with explanatory variables contained in $\mathbf{z}_j$. In the current context the number of observed disasters by disaster type are used as explanatory variable (To check robustness alternative specifications are employed, see Section 6). The count of positive disaster fatalities in turn are explained by a set of country characteristics, the level of economic development and respective measures of social inequality. Explanatory variables and controls are contained in $\mathbf{x}_j$. In the next subsection the various specifications employed will be discussed in some detail.

Kahn (2005) used a similar methodological approach based on the ZINB model on the role of income, geography and institutions in the context of natural disasters. The estimations in the present paper are undertaken using the ZINB module integrated in Stata 14.

3.3 The empirical strategy

After defining configurations of estimates and sets of configuration the control variables will be discussed in some detail.

3.3.1 Definition of sets, configurations and specifications

For each independent variable of interest we estimate three configurations with six specifications or models. We call these 18 estimation models an analytical set for a given variable. Our results are derived from the main set and enforced by multiple robustness sets. The construction of the main set is now laid out in detail.

The ZINB estimation model is a two-step estimation procedure. The first step consists of a logit regression that characterizes the excess zeroes in the data. In the main set these are explained by the count of occurrences of the different disaster types. The second step includes different control variables to account for unobserved heterogeneity.

Each specification of the second step of the ZINB model has a general part and a specific part. In the general part which is present in all models, we control for the number of disaster occurrences (*occur_drought*, *occur_flood*, *occur_extremetemp*, *occur_storm*) for the log of a country's area (*ln_area*), the log of its population (*ln_pop*) and the log of per-capita GDP (*ln_pc_gdp*). In the specific part the share of urban population (*urban_pop*), a democracy dummy (*democ*), a measure of corruption perception (*ti_cpi*), the government spending for education as a percentage of GDP (*gov_exp_edu_gdp*) and a measure of ethnic fractionalization (*al_ethnic*) is added.

Since it is not obvious what is the correct model, in the first configuration each specification contains only one of the specific controls. In the second configuration the controls are included cumulatively so that specification 6 contains the full set of control variables. Configuration 3 repeats the setup of configuration 2 but adds a variable measuring the rule of law (*wbgi_rle*). Configuration 3 is included since the rule of law

(like corruption perception) has a strong tendency to fundamentally change estimation results.[11]

Data availability differs across control variables, both in terms of country and year coverage. Accordingly, the sample size can change considerable across specifications within a set. However, we take the fact that estimation results are unchanged across varying samples as a first indication of their robustness in the sense that results are not driven by a specific sample of countries and years.

3.3.2 Discussion of control variables

The number of disaster occurrences has a direct effect on fatalities. If the disaster probability is naively assumed to be constant for each disaster, more disaster result in higher fatalities numbers. The marginal effect of an additional disaster is ambiguous. It might be positive if previous disasters reduce the resilience of society or might be negative if society can better cope with disasters due to increased experience and better preparation (Schumacher and Strobl 2011). The area of a country will influence the number and maybe also types of climate hazards occurring and ceteris paribus also influences population density which is of course a central determinant of disaster fatalities. This is even more so for the population: a higher population exposes ceteris paribus more people to a given hazard and accordingly should lead to higher casualty numbers. The level of socio-economic development as measures by the log of per capita GDP (in PPP) is one of the central determinants of vulnerability and adaptive capacity and higher levels of development are generally expected to lower disaster fatalities (e.g. Fankhauser and McDermott 2014, Raschky 2008).

The urban population is often argued to be more vulnerable because of congestion effects and strong dependency on functioning supply chains. On the other hand the rural population is seen to be more vulnerable due to a higher dependency on local resources, lower incomes and missing infrastructure (Cutter et al. 2003). Certainly, the population density is higher in cities, so when a city is exposed to a climate hazard, more fatalities are to be expected than if a comparable hazard happens on the countryside. For a country of a given area a higher share of urban population concentrates the population in some urban areas which might or might not be disaster prone. The effect of democracy is debated in the literature. In general it is thought that democracies entail better institutions and higher levels of social participation which both contribute to a society's resilience (Adger et al. 2005, Agrawal 2010, Raschky 2008). The corruption perception index (CPI) provided by Transparency International proxies the extent of corruption in society. Corruption can be understood as a malfunctioning of institutions, negatively affecting resilience and the capacity to cope (e.g. Banuri and Eckel 2012). Government spending on education as a fraction of GDP accounts for the relative use of resources for education which in general is thought to reduce vulnerability and increase resilience (Muttarak and Lutz 2014). Ethnic fractionalization is a measure of the degree of ethnic homogeneity in society. In general it is thought that homogeneity facilitates cooperation and the provision of public goods which both foster resilience through increasing adaptive and coping capacities (Alesina and La Ferrara 2000). The rule of law measure used in configuration 3 is a further measure of institutional quality with higher values expected to increase resilience thus lowering fatality rates.

[11] The World Bank provides six distinct measures of institutional quality, the other measures however are mostly insignificant.

4. Descriptive Statistics – Looking at the Data

In the present section we take a more detailed look at the data employing descriptive statistics, time trends and geographical visualizations to get a better understanding of the dependent (disaster fatalities) and explanatory variables (social inequalities, disaster occurrence, controls). We first describe the sample before taking a closer look at fatalities and disaster count data from EM-DAT. Then the explanatory variables of interest measuring social inequalities are explored in some detail. Thirdly, we consider further control variables.

In this section the data is taken at face value. Caveats regarding completeness and reliability of data are only mentioned on the side since they have been discussed in some detail in Section 2.

4.1 Sample

The basic sample comprises data for 206 countries over a timeframe of thirty-five years from 1980 till 2014. All countries in the sample are listed in Table A2 in the Annex. Sample size might vary considerably contingent on which control variables are included. Especially for the small island developing countries (SIDS) there is a lot of missing information.

4.2 Climate related extreme weather events

First we consider disaster occurrence. As a second step disaster fatalities will be described in some detail.

4.2.1 Disaster occurrence

Table 3a depicts the descriptive statistics for the whole sample including all zero values. There are 7210 country/year observations. On average there is about one disaster in each year in each country. Floods are the most common disasters, followed by storms. Droughts and extreme temperature events are rather rare events. There are a lot of country/year observations without any disaster observed. However there are also observations with up to 33 disasters occurring.

Table 3a. Number of disaster occurrence by disaster type, full sample.

Variable	# Obs.	Mean	Std. Dev.	Min	Max
all	7,210	1.08	2.44	0	33
Droughts	7,210	0.07	0.27	0	3
Floods	7,210	0.53	1.24	0	20
Storms	7,210	0.41	1.42	0	27
Extreme temp.	7,210	0.07	0.29	0	3

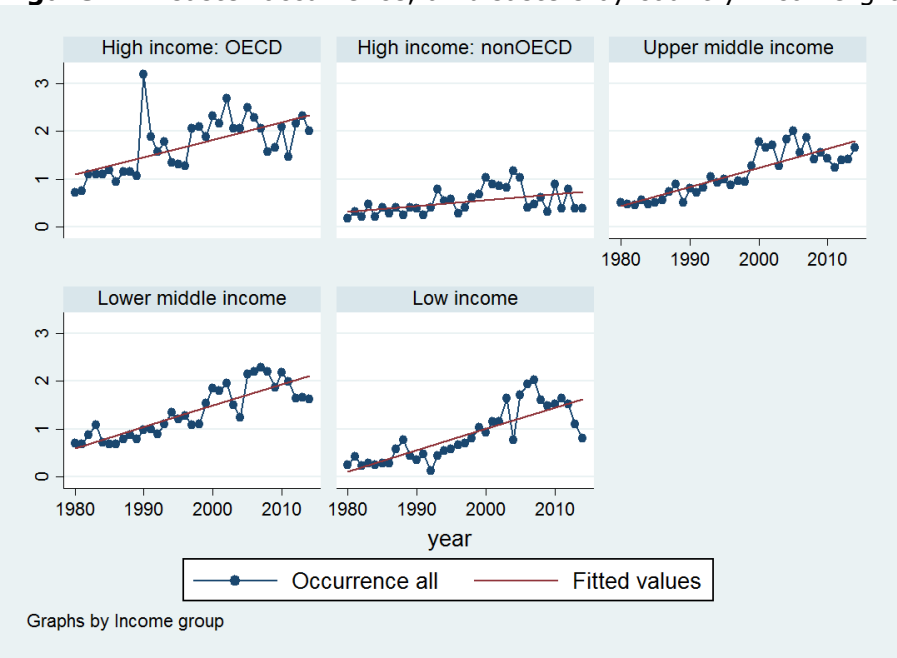
In Table 3b only non-negative occurrences are shown. Accordingly, there are 3072 country/year observations (43%) with at least one of the disaster types occurring. Overall, EM-DAT records 500 droughts, 2050 floods, 1379 storms and 404 extreme temperature events for the sample under consideration.

Table 3b. Number of disaster occurrence by disaster type, only observations with at least one disaster.

Variable	# Obs.	Mean	Std. Dev.	Min	Max
all	3,072	2.54	3.21	1	33
Droughts	500	1.03	0.20	1	3
Floods	2,050	1.88	1.71	1	20
Storms	1,379	2.16	2.62	1	27
Extreme temp.	404	1.18	0.44	1	3

To understand the distribution of disaster occurrence across time we average the number of occurrences over country income groups as defined by the World Bank. The evolution by income-group for all disasters is shown in Figure 1. There is an increasing time trend. Also on average disaster occurrence seems to be more frequent in OECD countries than in all other income groups. The increase in disaster frequency over time could be contributed to effects of climate change. However, both the time trend and the distribution of frequencies across income groups could also be driven by a recording bias across time and level of development, as discussed in Section 2.

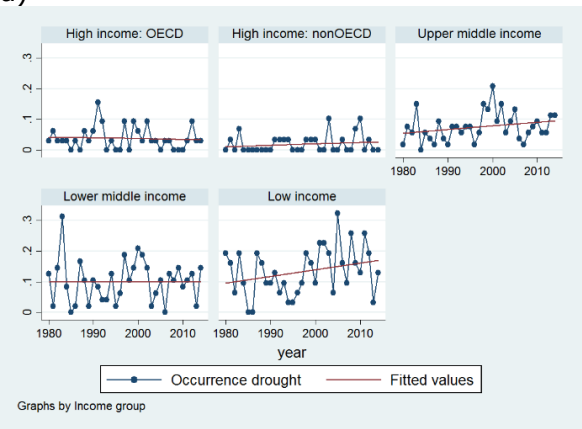
Figure 1. Disaster occurrence, all disasters by country-income-group.



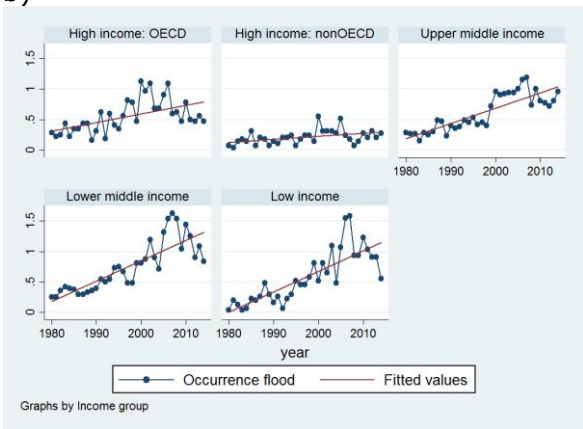
In Figure 2 the time trends across income-groups for the four disaster types are depicted individually. It is interesting to note the heterogeneity across disaster types. For drought occurrence (panel a) there is a positive time trend in upper middle and low income countries. In contrast, extreme temperature events (panel d) seem to become more frequent in OECD countries and do not exhibit any trend over time in low income countries.

Figure 2. Disaster occurrence by country-income-group time for drought (a), flood (b), storm (c), extreme temperature (d).

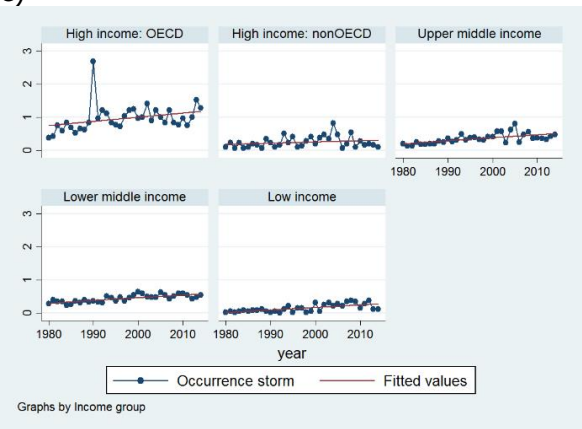
a)



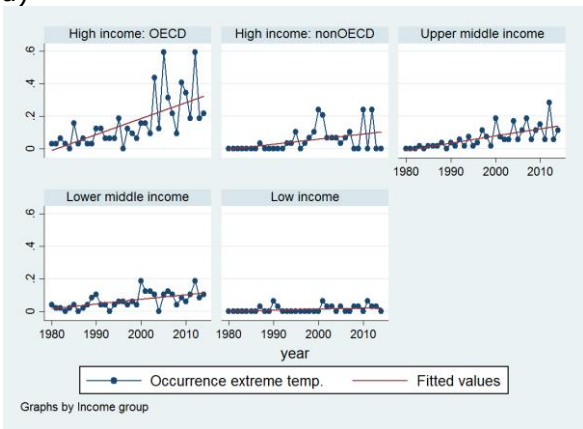
b)



c)

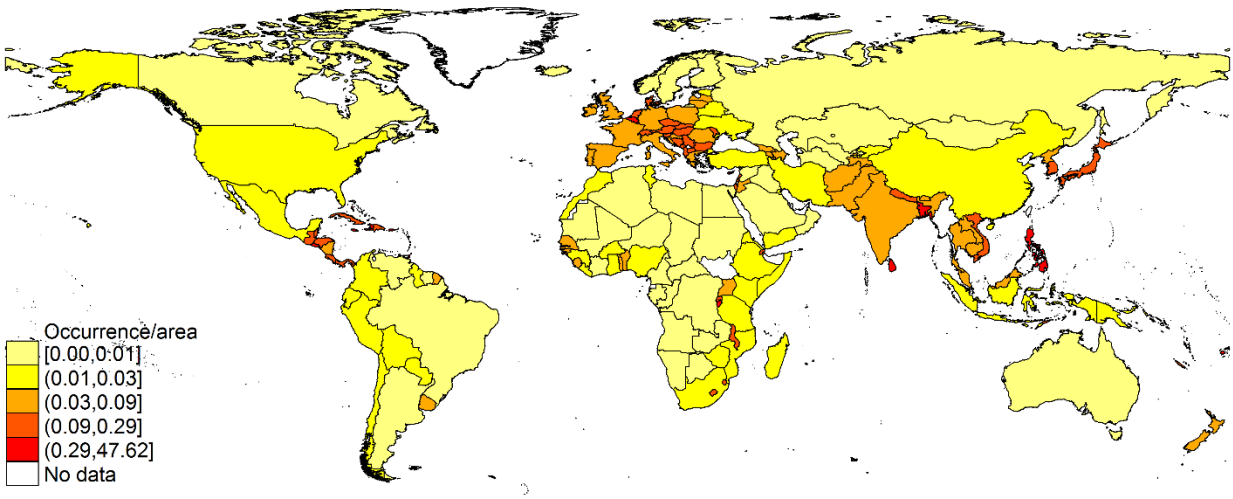


d)



A quite pronounced positive time trend for floods (panel b) is observed for all income groups but for non-OECD high income countries. For storms (panel c) a small positive time trend is apparent throughout, with storms slightly more frequent in OECD countries.

Map 1. Disaster occurrence per square kilometre.



A statistical perspective on disaster occurrence might ignore that disaster intensities can differ considerably across disasters. In disaster event data like the EM-DAT there is no measure of disaster intensity but only disaster outcomes (fatalities, people affected, economic damage) available.

4.2.2 Disaster fatalities

Disaster fatalities constitute the main dependent variable. The measurement of disaster fatalities is of course even more problematic than the measurement of disaster occurrences with an even more pronounced development bias. Contrary to disaster occurrence there is however no other alternative way to measure disaster fatalities. The descriptive statistics for casualties in climate related disasters are provided in Table 4a for the full sample and in Table 4b for the country/years where at least one disaster occurred.

Table 4a. Total disaster fatalities by disaster type, full sample.

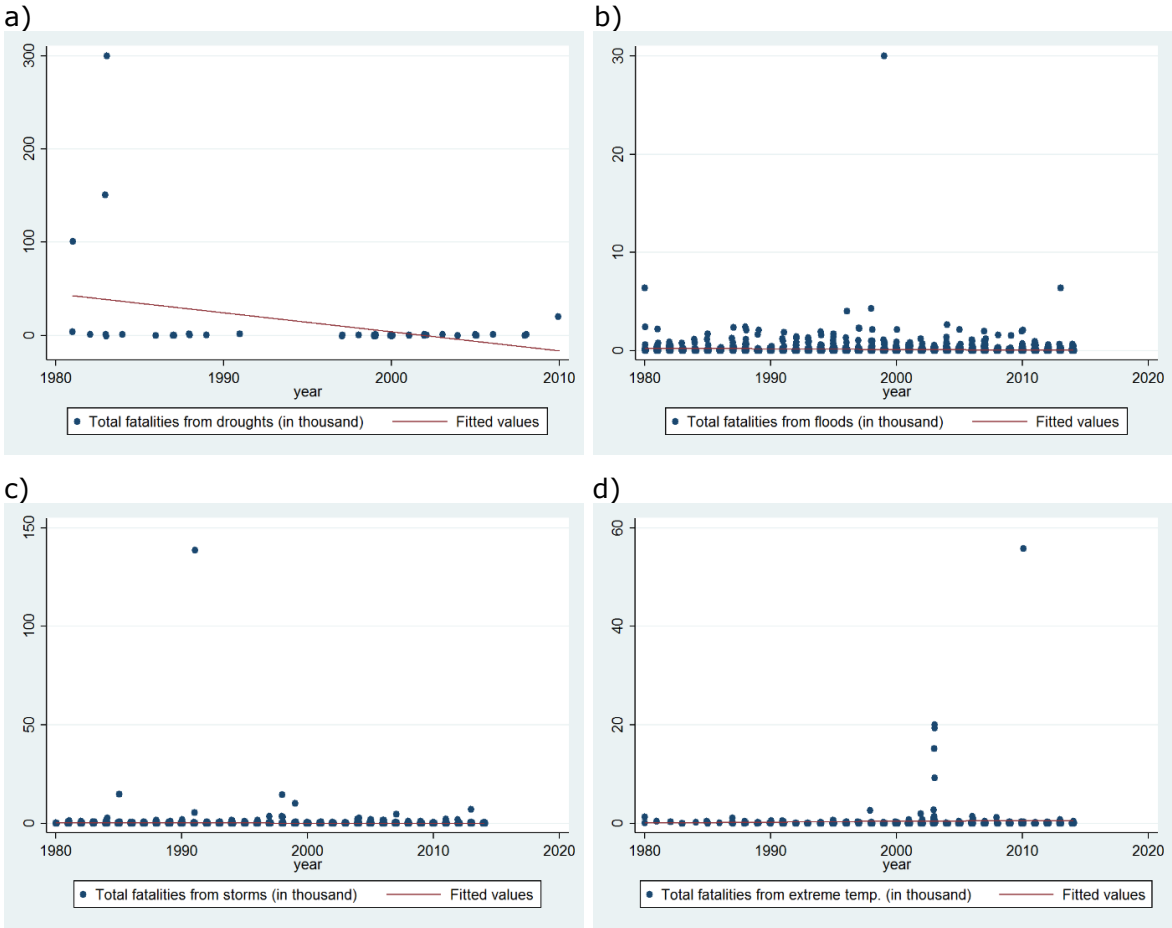
Variable	# Obs.	Mean	Std. Dev.	Min	Max
All	7,210	178.96	4539.41	0	300000
Droughts	7,210	80.66	4128.43	0	300000
Floods	7,210	32.13	404.04	0	30005
Storms	7,210	42.87	1669.02	0	138987
Extreme temp.	7,210	23.30	767.40	0	55760

Table 4b. Total disaster fatalities by disaster type, only observations with at least one disaster.

Variable	# Obs.	Mean	Std. Dev.	Min	Max
All	3,072	420.01	6947.71	0	300000
Droughts	500	1163.08	15651.54	0	300000
Floods	2,050	113.02	751.80	0	30005
Storms	1,379	224.14	3812.12	0	138987
Extreme temp.	404	415.77	3220.38	0	55760

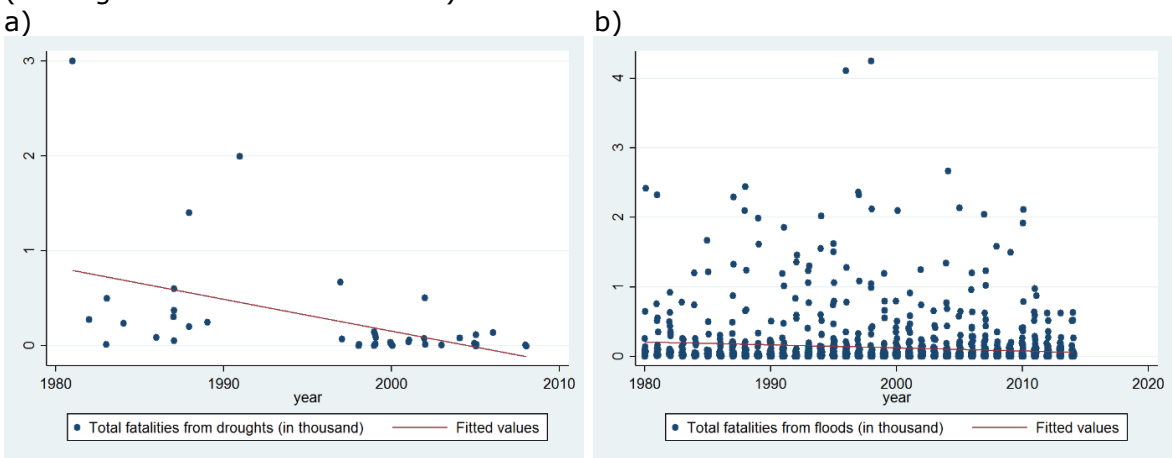
On average 420 people die when a disaster strikes with droughts being the most deadly and floods the least deadly events. Extreme temperature events result in an average of 415 fatalities per disaster. Since they are quite rare events, overall there are on average about 23 causalities per country/year observation. Figure 3 depicts all positive (i.e. >0) disaster fatality counts by disaster type over time. This representation clearly shows that average fatality numbers are rather misleading. There are very few disasters with very high causality numbers. If these extreme values are excluded the considerable variance becomes obvious, this is shown in Figure 4. There are still many disasters with thousands of fatalities across disaster types.

Figure 3. Non-zero counts of disaster fatalities by disaster-type over time for drought (a), flood (b), storm (c), extreme temperature (d).

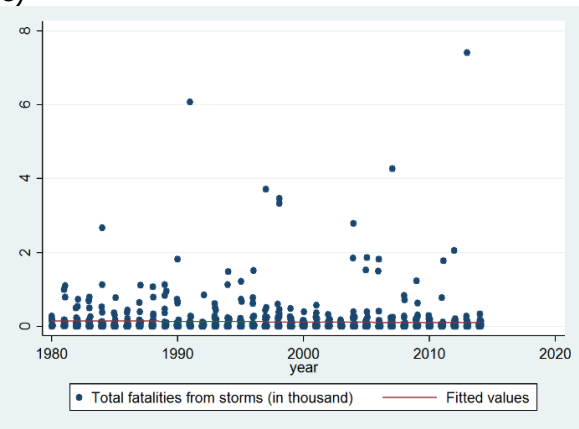


For droughts the trend line indicates clearly decreasing fatality counts. For the other disaster types there is also a moderate decreasing trend in fatalities over time. It is possible that this developments result from the global efforts on disaster risk reduction (e.g. Hyogo Framework). The geographical distribution of disaster fatalities per capita, averaged over time, are displayed in Map 2.

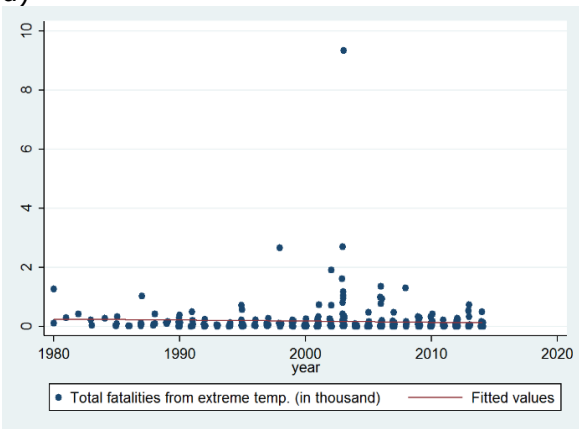
Figure 4. Non-zero counts of disaster fatalities by disaster-type over time without extreme observations for drought (a), flood (b), storm (c), extreme temperature (d) (like Figure 3 with censored data).



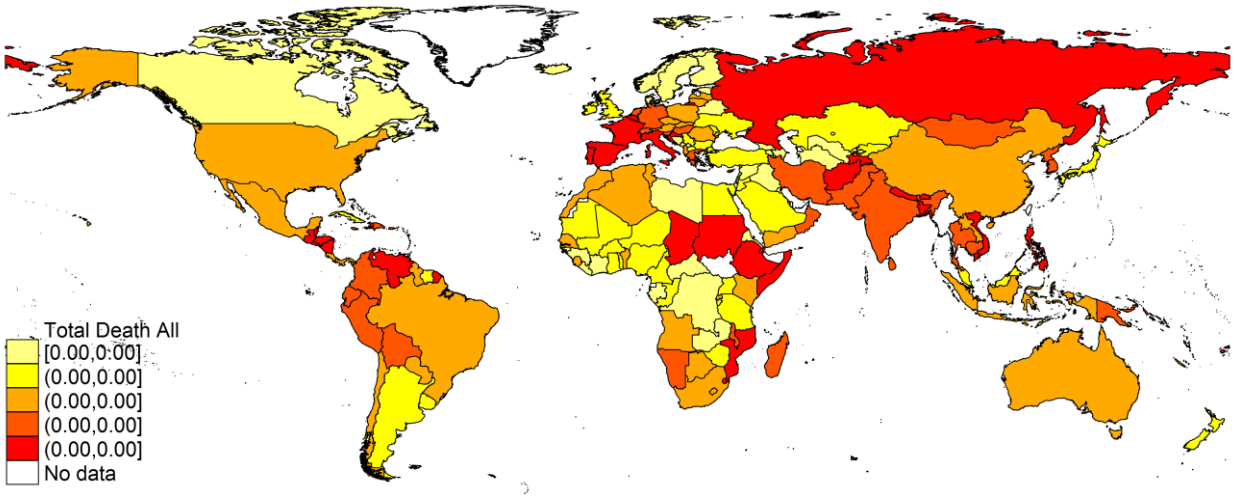
c)



d)



Map 2. Disaster fatalities per capita over time (average 1980-2014).



4.3 Social inequalities

This analysis considers two dimensions of social inequality: income inequality and gender inequality. Both are multifaceted, complex concepts and problems of measurement are discussed in some detail in Section 2. We first describe the measures used to capture income inequality and then depict gender inequality.

4.3.1 Income inequality

The distribution of incomes is measured using the Gini coefficient of the income distribution for market incomes (*gini_market*) and after tax and transfer incomes (*gini_net*). Data source is the Standardized World Income Inequality Database (SWIID). In addition the World Bank provides own estimates of the Gini coefficient (*gini_wb*). As apparent in Table 5, these measures of the income distribution are only available for a subset of country/year observations. At least some information on the income distribution is available for 160 countries, with length and completeness of the time series varying across countries. The coverage of the World Bank data is even more limited. However, we use the World Bank estimates of the Gini coefficient for robustness checks and accordingly report the descriptive statistics in Table 5. The lower panel of

Table 5 reports the descriptive statistics for those country/years for which SWIID and World Bank estimates are available. This comparison suggests that the Word Bank estimates refer to the income distribution after taxes and transfers.[12]

Table 5. Descriptive statistics for Gini of net, market and available incomes (*gini_net*, *gini_market*, *gini_wb*).

Variable	# Obs.	Mean	Std. Dev.	Min	Max
gini_net	3,380	37.66	10.27	15.05	71.33
gini_market	3,376	43.77	8.64	20.11	77.97
gini_wb	1,081	40.47	10.39	16.23	74.33
Common observations for SWIID and World Bank					
gini_net	895	39.09	9.71	16.82	69.79
gini_market	895	44.21	7.72	20.11	70.96
gini_wb	895	40.52	10.58	16.23	74.33

Table 6 shows the average Gini coefficient across time and country by country income group. Countries which are economically more developed have on average a larger difference between the concentration of market and post-tax post-transfer incomes. This indicates that redistributive welfare states are more developed in richer countries. The average concentration of both, market and net incomes is higher in less developed countries. This perspective however neglects changes over time.

Table 6. Gini of net and market income by country-income-group.

	gini_net		gini_market		
Income group	Mean	Std. Dev.	Mean	Std. Dev.	Freq.
High income: OECD	28.95	5.50	42.12	4.74	32
High income: nonOECD	35.38	6.24	43.43	6.52	14
Upper middle income	41.39	10.02	44.58	9.40	44
Lower middle income	41.74	8.21	44.06	7.59	42
Low income	44.29	6.76	45.35	6.91	27
Total	38.94	9.56	43.98	7.48	159

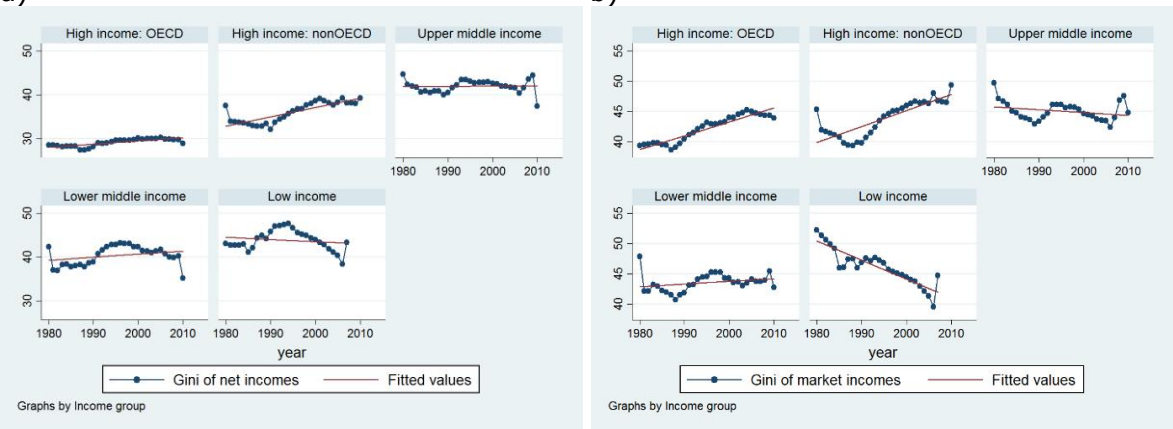
The development of income inequality of net and market incomes for country income groups over time is depicted in Figure 5. Panel a shows the evolution of the Gini of net incomes, panel b the Gini of market incomes. Averaging across countries within income groups there is no change in income concentration in OECD countries. High income non-OECD countries and upper and lower middle income countries seem to have experienced a slight increase in income inequality after taxes and transfers. In low income countries

[12] From the metadata it seems that the World Bank provides the Gini of available household incomes.

there seems to be rather a downward trend in income concentration. The picture is different for market incomes as shown in panel b. Income concentration has increased in high income countries, remained by and large unchanged in middle income countries and has considerably decreased in low income countries.

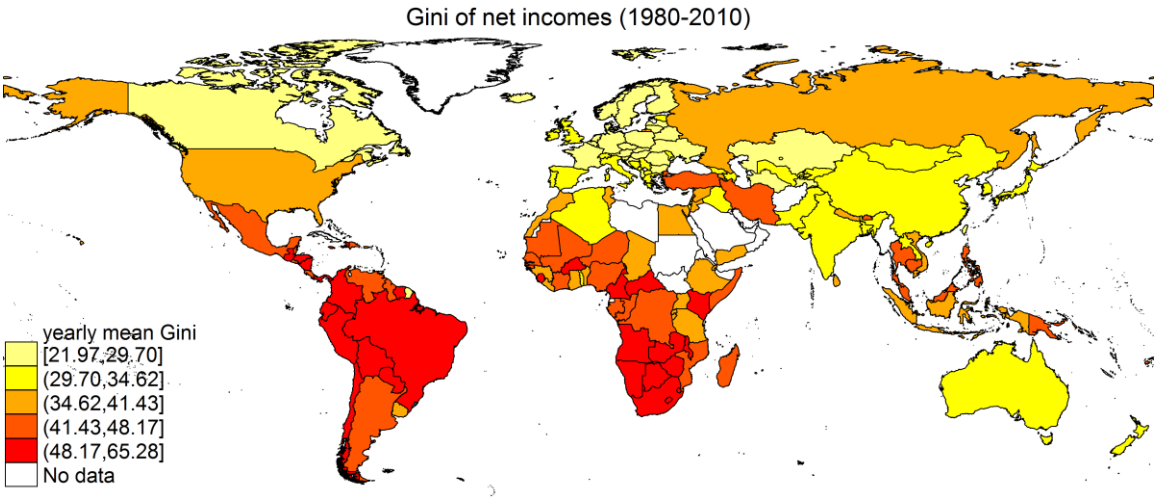
Figure 5. Gini of net (a) and market (b) incomes over time by country-income-group.

a) b)



Map 3 depicts the average Gini-coefficient of net incomes over all available years for each country.

Map 3. Average Gini of net incomes across countries.



4.3.2 Gender inequality

The problems of defining and measuring gender equality, as discussed in Section 2, are being met using a multiplicity of measures to approximate the phenomenon. Table 7 depicts the description of all employed variables which can be sorted in four groups: the variables from the CIRI data on women's political, economic and social rights, the portion of seats held by women in national parliament (*female_mp*), female labour force participation (*female_lfp*) and female education (*ratio_enroll_primary*, *ratio_enroll_second*, *ratio_enroll_tertiary*, *ratio_prim_sec*). Data availability differs across variables with women political rights (*wopol*) and ration of female to male pupils enrolled in primary education (*ratio_enroll_primary*) having the broadest coverage. Further insights provided by Table 7 are that there are countries with no women in

parliament, there are countries where female labour force participation is higher than male but no countries where women do not work at all. For education there are countries where women do not receive any schooling (ratio=0) but also countries where more women receive primary, secondary or tertiary education then men.

Table 7. Description of measures for gender equality.

Variable	Variable Name	# Obs.	Mean	SD	Min	Max
Women political rights*	*wopol*	4,637	1.83	0.60	0	3
Women economic rights*	*wecon*	4,587	1.32	0.70	0	3
Women social rights*	*wosoc*	3,460	1.26	0.85	0	3
Proportion of seats held by women in national parliaments Income (%)	*female_mp*	3,134	15.37	10.63	0	63.80
Labor force, female (% of total labor force)	*female_lfp*	3,792	40.14	9.28	10.39	56.00
Ratio of female to male primary enrollment (%)	*ratio_enroll_primary*	4,612	93.02	12.70	0	143.33
Ratio of female to male secondary enrollment (%)	*ratio_enroll_second*	3,742	92.95	22.22	0	208.14
Ratio of female to male tertiary enrollment (%)	*ratio_enroll_tertiary*	3,124	97.54	48.22	0	642.02
Ratio of girls to boys in primary and secondary education (%)	*ratio_prim_sec*	3,624	93.97	14.17	0	143.93

*see Table A1 in the Appendix for detailed description

In Table 8 - Table 10 the variables on gender inequality are described by country income groups, aggregated over countries and years. For women economic (*wecon*) and social rights (*wosoc*), presented in Table 8, there is a monotonic increase in gender equality with income. In richer countries there are on average more gender rights. For women political rights (*wopol*) the high income non-OECD countries exhibit the lowest level, the OECD countries the highest level. The share of seats in parliament held by women (*female_mp*) is closely related to political rights (Table 9). Here we observe a u-shaped relation. The share of seats held by women is on average highest in high income OECD countries, low for non-OECD and middle income countries and comparatively high in low income countries. A similar u-shaped pattern is observed for female labour force participation (*female_lfp*) with the difference that labour force participation of women is on average highest in low income countries followed by high income OECD-countries.

Table 8. CIRI-variables described by country income groups.

	wopol			*wecon*			*wosoc*		
Country Inc. Group	Mean	SD	Freq.	Mean	SD	Freq.	Mean	SD	Freq.
High income OECD	**2.18**	0.49	945	**2.00**	0.58	938	**2.22**	0.74	719
High income non-OECD	**1.61**	0.85	407	**1.41**	0.75	406	**1.22**	0.95	279
Upper middle income	**1.79**	0.57	1,248	**1.30**	0.62	1,231	**1.15**	0.68	913
Lower middle income	**1.73**	0.50	1,206	**1.05**	0.55	1,194	**0.91**	0.61	899
Low income	**1.72**	0.61	831	**0.93**	0.51	818	**0.84**	0.54	650
Total	**1.83**	0.60	4,637	**1.32**	0.70	4,587	**1.26**	0.85	3,460

Table 9. Female members of parliament and labour force participation by country income groups (in %).

	female_mp			*female_flp*			*ratio_flp*		
Country Inc. Group	Mean	SD	Freq.	Mean	SD	Freq.	Mean	SD	Freq.
High income OECD	**22.83**	10.72	595	**43.83**	3.47	726	**74.26**	9.50	768
High income non-OECD	**14.29**	9.53	295	**38.23**	11.75	311	**66.02**	16.29	504
Upper middle income	**14.29**	10.03	896	**37.06**	9.77	1,036	**60.86**	20.26	1,128
Lower middle income	**11.78**	8.68	848	**37.92**	9.04	1,032	**62.42**	20.76	1,104
Low income	**15.15**	10.97	500	**45.11**	8.48	687	**81.71**	20.80	720
Total	**15.37**	10.63	3,134	**40.14**	9.28	3,792	**67.87**	20.13	4,224

For education we observe in Table 10 a positive relationship between higher income and a higher ratio of female to male education participation. Note that secondary and tertiary enrolment ratios are highest in high income non-OECD countries. Gender equality in terms of education participation is granted if the enrolment ratio equals 100%. The fact that female participation in secondary and tertiary education in the three top income groups are higher than male participation also indicates a form of gender inequality.

Table 10. Female to male enrolment ratio by country income groups (in %)

	Primary enrollment			Secondary enrollment			Tertiary enrollment		
Country Inc. Group	Mean	SD	Freq.	Mean	SD	Freq.	Mean	SD	Freq.
High income OECD	**99.45**	1.54	954	**101.62**	5.66	925	**111.31**	28.18	919
High income non-OECD	**98.55**	5.60	477	**103.07**	12.19	402	**128.72**	50.38	353
Upper middle income	**97.00**	5.30	1,186	**101.46**	15.56	1,028	**116.17**	48.89	750
Lower middle income	**92.10**	11.78	1,250	**89.08**	24.06	876	**80.90**	39.99	673
Low income	**76.43**	17.98	745	**58.80**	20.21	511	**35.94**	20.55	429
Total	**93.02**	12.70	4,612	**92.95**	22.22	3,742	**97.54**	48.22	3,124

To better understand how gender rights evolved over time Figure 6 and 7 depict a subset of the variables in Table 7. Women political rights and the closely related share of women in parliament have increased over time in all country groups (Fig. 6 a, b). For women's economic rights the time trend is less obvious. In Figure 6c there seems to be a slight increase in high income countries, no change over time in middle income countries and a decline in economic freedoms in low income countries. Women social rights are depicted in Figure 6d, averages show a similar evolution over time as economic rights.

Figure 6. Women rights (a, c, d) and share of female members of parliament (b) over time by country-income-group

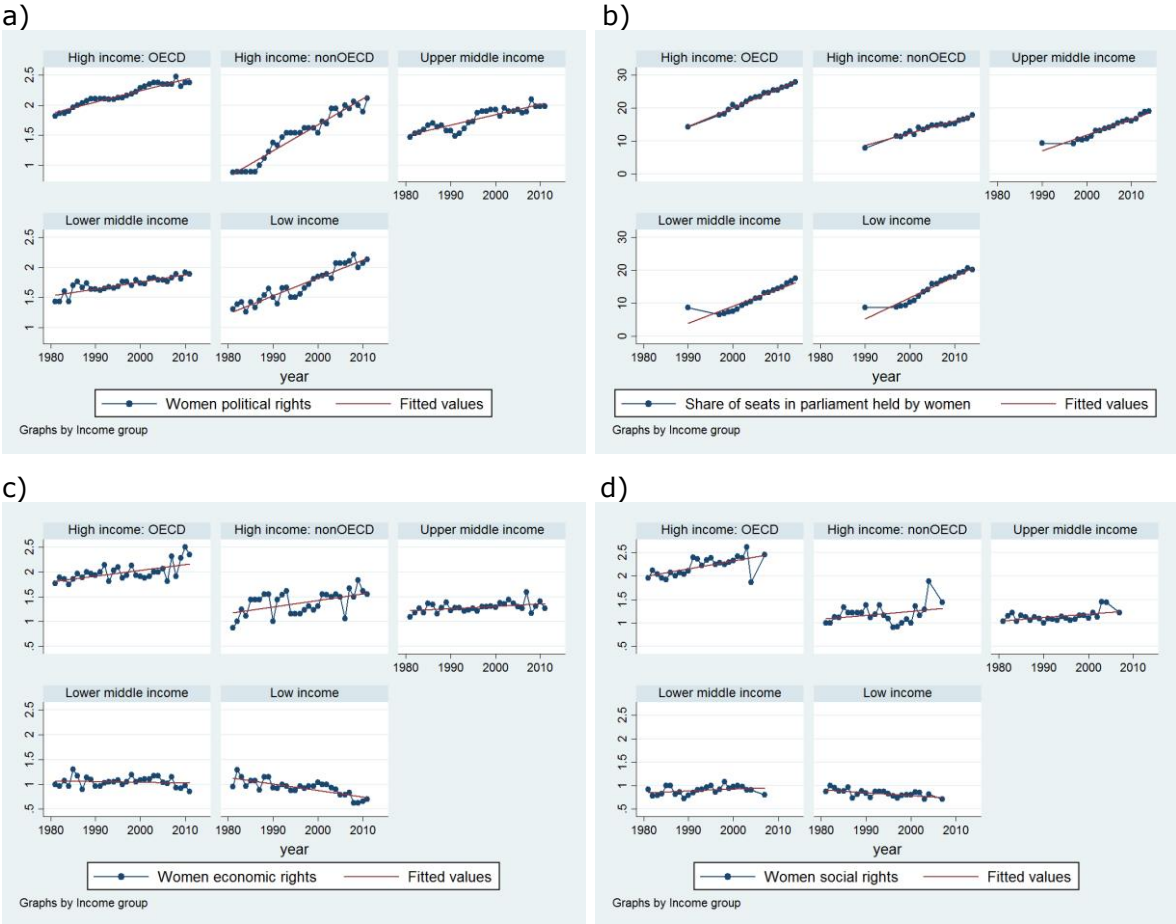
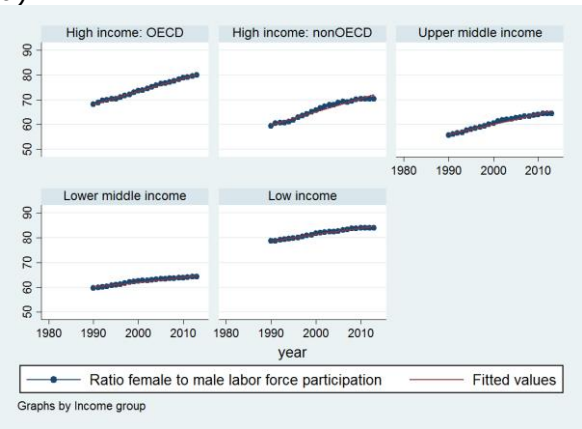


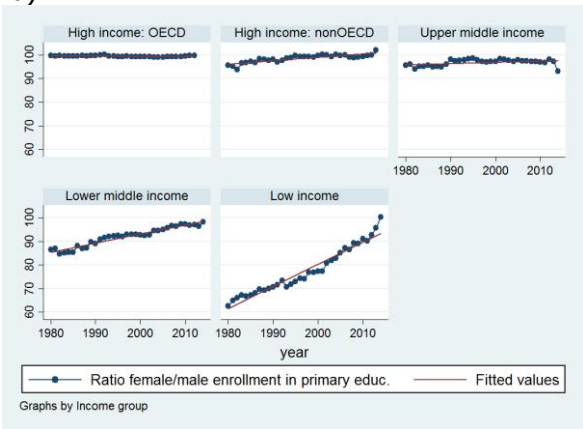
Figure 7 indicates gender equality in terms of labour force and education participation. The ratio of female to male labour force participation is increasing over time in all country income groups and is on the highest level in low income countries. The share of women in the labour force is not depicted since the figure is qualitatively alike. The evolution of female education participation is similar for primary and secondary education (Fig. 7b, c). For non-tertiary education there is basically gender equality for high income countries and upper middle income countries. The latter experienced some increase in female education enrolment since 1980. For lower middle income countries and low income countries there is a marked increase in female education participation on primary and secondary level. For tertiary education, depicted in Figure 7d, female to male enrolment ratios increase in all country income groups. However, in high and upper middle income countries there are more women enrolled then men, i.e. the ratio is higher than 100%. It will also be explored if this form of gender equality affects aggregate vulnerability in the context of extreme weather events.

Figure 7. Female labour force participation (a) female to male enrolment ratio in primary (b), secondary (c) and tertiary (d) education over time by income group.

a)



b)



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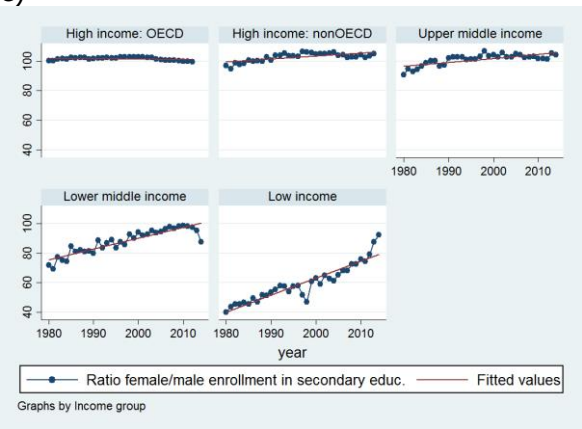
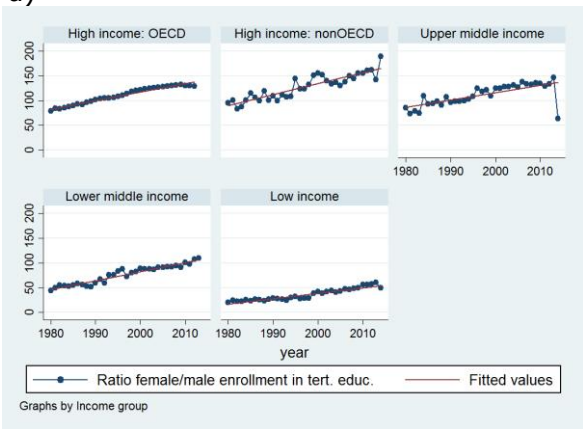


d)



Maps, depicting the geographical distribution of all these measures of gender (in)equality are relegated to the Appendix (Map A1-A9).

4.4 Correlation among different measures of gender and income inequality

The correlation coefficients among our distributional variables of interest are shown in Table 11.[13] It is interesting to note that all measures of gender equality are significantly negatively related with the Gini of net incomes. If after tax and transfer incomes are more concentrated, there is on average less gender equality. This is not true for the correlation with the Gini of market incomes. This indicates that countries with functioning welfare state institutions also exhibit higher levels of gender equality.

[13] The correlation coefficients among the variables for education participation are omitted for brevity. They are all significantly positive and high (>.5).

Table 11. Correlation among measures of gender and income inequality.

	Gini net	Gini market	*wopol*	*wosoc*	*wecon*	Female mp	Female lfp
Gini market	0.7507*	1.0000					
wopol	-0.2796*	-0.0250	1.0000				
wosoc	-0.4647*	-0.0975*	0.4475*	1.0000			
wecon	-0.3986*	-0.0599*	0.3648*	0.7412*	1.0000		
Female mp	-0.3195*	0.0657*	0.6661*	0.4714*	0.3259*	1.0000	
Female lfp	-0.1270*	0.0512*	0.3796*	0.2969*	0.2047*	0.2994*	1.0000
ratio primary	-0.1660*	0.0704*	0.2735*	0.3241*	0.3024*	0.2190*	0.1299*
ratio second.	-0.0955*	0.1181*	0.2420*	0.3453*	0.3217*	0.1517*	0.0570*
ratio tertiary	-0.2075*	0.0500*	0.2457*	0.3508*	0.3277*	0.1862*	0.0713*
ratio prim+sec	-0.1436*	0.1083*	0.2716*	0.3696*	0.3344*	0.2069*	0.1261*

Note: * p<.05

4.5 Further controls

To reduce unobserved heterogeneity across countries we include multiple control variables which are in general considered important in the vulnerability literature and as such might systematically influence the number of fatalities.

Table 12. Descriptive statistics of control variables.

Variable	Variable name	Obs.	Mean	Std. Dev.	Min	Max
population	*population*	6,515	2.98e+07	1.16e+08	7525	1.36e+09
Ln(population)	*ln_pop*	6,515	15.26	2.21	8.93	21.03
area	*area*	6,605	704339.2	1939177	20	1.71e+07
Ln(area)	*ln_area*	6,605	11.30	2.71	3.00	16.65
per capita GDP, PPP	*gdp_pc_ppp*	4,187	13184.08	15144.13	142.02	138024.9
Ln(per capita GDP, PPP)	*ln_pc_gdp*	4,187	8.84	1.21	4.96	11.84
Rule of law	*wbgi_rle*	2,504	-0.12	0.98	-2.67	2.00
Urban population	*pop_urban*	6,518	52.00	24.07	4.34	100.00
Democracy	*democ*	7,210	0.62	0.49	0.00	1.00
TI-corruption perception index	*ti_cpi*	2,339	4.23	2.19	0.40	10.00
Government edu. exp. (% of GDP)	*gov_exp_edu_gdp*	2,665	4.57	2.08	0.00	44.33
Ethnic fractionalization	*al_ethnic*	5,402	0.43	0.26	0.00	0.93
Value added of agri. sector (% GDP)	*valueadded_agri*	4,951	17.70	14.72	0.00	93.98
Poverty gap (at 2$ per day in %)	*poverty_2*	936	12.33	15.24	0.00	77.20
Poverty headcount ratio (at 2$ per day in % of population)	*poverty_ratio 2*	936	27.92	28.24	0.00	98.98
Latitude	*lp_lat_abst*	5,646	0.28	0.19	0.00	0.72

5. Results

In the following the results from the main set of regressions for gender equality, income inequality and the two types of (in)equality together are presented and interpreted.

5.1 Gender equality

The relation of gender equality on disaster fatalities is firstly analysed with proxies from female education participation. Secondly, female labour force participation will be analysed. Finally, we will look at measures of female rights and political participation.

To make the analysis comprehensible the first result is presented in full detail, i.e. all six specifications of configuration 1 are depicted. The multiplicity of different variables used to approximate social inequalities, the high number of specifications and especially the extensive robustness tests make it necessary to present our results in an ever more aggregated way.

5.1.1 Female education participation

Table 13 depicts all regression coefficients obtained in all six specifications of configuration 1, i.e. auxiliary controls are included individually, for the ratio of female to male enrolment in secondary education. As could be seen in the descriptive statistics, there are a number of countries where more women participate in secondary education then men. This of course also constitutes a form of gender inequality. Since any form of unequal education participation constitutes a form of gender inequality, a non-linear relation between female education participation and vulnerability can be expected. To account for this non-linear relation the ratio of female/male enrolment in secondary education, the squared variable is also included in the estimation. The estimated coefficients are negative and significant at a .1% level. In contrast the coefficients for the squared values are significantly positive.

This means that there is an inverted u-shaped relation between female secondary education participation and the number of disaster fatalities. Increasing the ratio of women enrolled decreases the likelihood of more disaster fatalities up to the point of equal enrolment. Further increases in the relative enrolment of women increase the likelihood of higher numbers of disaster casualties.

What do the other coefficients tell us? A higher number of floods and extreme temperature events increase the likelihood of observing higher death counts, the coefficients for storms and droughts are not significantly different from zero. A bigger population significantly increases the likelihood of more disaster fatalities, while a bigger land area reduces it. Also, in general a higher level of socio-economic development as measured in the log of per capita GDP has, as hypothesized, a significantly negative effect on disaster fatalities.

Regarding the auxiliary controls, all variables but democracy have the expected sign, corruption and education expenditure are significant. The corruption perception index gives higher values to countries with a lower corruption perception. Lower levels of corruption perception significantly reduce the likelihood of high numbers of disaster fatalities. This is in line with the general presumption, that better functioning institutions reduce vulnerability.

Table 13. Female/male enrolment ratio secondary education and square.

totdeath_4d	(1)	(2)	(3)	(4)	(5)	(6)
Occurrence:						
drought	-0.164	-0.153	-0.167	-0.100	-0.042	-0.170
	(-1.06)	(-0.99)	(-1.08)	(-0.56)	(-0.22)	(-1.09)
flood	0.127**	0.130**	0.128**	0.011	0.138**	0.121**
	(3.11)	(3.18)	(3.13)	(0.28)	(2.65)	(2.90)
extreme temp.	1.613***	1.624***	1.600***	1.801***	2.418***	1.637***
	(10.54)	(10.56)	(10.22)	(10.09)	(13.12)	(10.49)
storm	-0.004	-0.003	-0.005	0.034	0.023	0.003
	(-0.15)	(-0.11)	(-0.20)	(1.04)	(0.75)	(0.11)
Ln(pop)	0.728***	0.733***	0.725***	0.903***	0.632***	0.758***
	(14.07)	(14.16)	(13.77)	(13.89)	(9.44)	(13.94)
Ln(area)	-0.179***	-0.190***	-0.173***	-0.266***	-0.170**	-0.216***
	(-3.69)	(-3.84)	(-3.41)	(-5.19)	(-2.82)	(-4.15)
Ln(pc_gdp)	-0.281***	-0.350***	-0.285***	-0.050	-0.430***	-0.252***
	(-4.21)	(-3.91)	(-4.21)	(-0.56)	(-4.91)	(-3.51)
Enrolment ratio secondary education	-0.187***	-0.180***	-0.185***	-0.263***	-0.080*	-0.191***
	(-6.62)	(-6.32)	(-6.44)	(-6.83)	(-2.00)	(-6.43)
Squared enrolment ratio second. edu.	0.001***	0.001***	0.001***	0.002***	0.001*	0.001***
	(7.88)	(7.37)	(7.53)	(8.10)	(2.41)	(7.67)
Urban pop		0.005				
		(1.16)				
Democracy			0.055			
			(0.38)			
Corruption perception				-0.168***		
				(-3.52)		
Government educ. expenditure					-0.115*	
					(-2.43)	
Ethnic fractionalization						0.347
						(1.25)
_cons	3.250*	3.428**	3.203*	3.067	2.096	2.978*
	(2.44)	(2.59)	(2.40)	(1.63)	(1.17)	(2.04)
inflate						
Occurrence						
drought	-20.712	-23.534	-21.962	-22.115	-22.842	-20.769
	(-0.00)	(-0.00)	(-0.00)	(-0.00)	(-0.00)	(-0.00)
flood	-25.655	-28.474	-26.902	-26.240	-26.973	-25.687
	(-0.00)	(-0.00)	(-0.00)	(-0.00)	(-0.00)	(-0.00)
extreme temp.	-27.159	-29.939	-28.416	-27.835	-27.338	-26.973
	(-0.00)	(-0.00)	(-0.00)	(-0.00)	(-0.00)	(-0.00)
storm	-26.148	-28.998	-27.391	-27.472	-27.578	-26.218
	(-0.00)	(-0.00)	(-0.00)	(-0.00)	(-0.00)	(-0.00)
_cons	23.871	26.694	25.121	24.371	25.523	23.931
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
lnalpha						
_cons	1.160***	1.160***	1.160***	1.133***	1.102***	1.154***
	(29.34)	(29.32)	(29.33)	(25.34)	(22.24)	(28.74)
N	2660	2660	2660	1641	1617	2500

Note: t-statistics in parenthesis. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001

The lower panel provides the coefficients of the first step logit regression to account for the zero observations. The coefficients for the number of occurrences of the different disasters are all negative. A higher number of occurrences reduces the likelihood of observing zero fatalities. In this configuration the coefficients are all insignificant. Especially for configuration 3 we often obtain significant coefficients. For each regression we perform the Vuong test which indicates throughout that the zero inflated model is to be preferred. In addition a likelihood ration test is performed to assure that the zero inflated negative binomial model is preferred to the zero-inflated poisson model.

For the other results of the main set only regression coefficients for the variables of interest will be reported.[14] Table 14 depicts the coefficients for the female/male enrolment ratios in secondary education for all three configurations (C1-C3).

Table 14. Coefficients for female/male enrolment ratio secondary education (*ratio_enroll_second*).

	est1	est2	est3	est4	est5	est6
		Share of urban pop	Democracy	Corruption perception	Gov. educ. expenditure	Ethnic frac.
C1: Individual						
Sec. educ. ratio	-0.187***	-0.180***	-0.185***	-0.263***	-0.080*	-0.191***
	(-6.62)	(-6.32)	(-6.44)	(-6.83)	(-2.00)	(-6.43)
ratio squared	0.001***	0.001***	0.001***	0.002***	0.001*	0.001***
	(7.88)	(7.37)	(7.53)	(8.10)	(2.41)	(7.67)
C2: Cumulative						
Sec. educ. ratio	-0.187***	-0.180***	-0.179***	-0.261***		-0.158*
	(-6.62)	(-6.32)	(-6.17)	(-6.34)		(-2.32)
ratio squared	0.001***	0.001***	0.001***	0.002***		0.001**
	(7.88)	(7.37)	(7.10)	(7.28)		(2.91)
C3: +rule of law						
Sec. educ. ratio	-0.088**	-0.096**	-0.087**	-0.108**	-0.169*	-0.148*
	(-2.85)	(-3.07)	(-2.64)	(-2.76)	(-2.42)	(-2.01)
ratio squared	0.001***	0.001***	0.001**	0.001***	0.001**	0.001**
	(3.31)	(3.61)	(3.04)	(3.31)	(3.04)	(2.64)

Note: Coefficients from ZINB estimation, t-statistics in parenthesis. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001. For missing entries the estimation process did not converge.

Accordingly, line 3-6 of Table 14 contain the same information about the effect of secondary enrolment ratios as Table 13. The coefficients are qualitatively similar in all three configurations C1-C3, so that there is some evidence for a statistical significant relation between female participation in secondary education and a society's vulnerability to climate related extreme weather events.

The results for primary education enrolment are depicted in Table 15. The estimation process does not converge for three specifications. Most other specifications indicate a negative relation between gender equality in primary education and vulnerability. However, when relative government expenditure is included in the estimation, insignificant positive coefficients result. Accordingly, there is only weak evidence for the importance of gender equality in primary education in reducing vulnerability.

[14] All complete estimation tables are available from the authors upon request.

Table 15. Coefficients for female/male enrolment ratio primary education (*ratio_enroll_primary*).

	est1	est2	est3	est4	est5	est6
		Share of urban pop	Democracy	Corruption perception	Gov. educ. expenditure	Ethnic frac.
C1: Individual						
Prim. educ. ratio		-0.154*		-0.520***	0.024	-0.179*
		(-2.16)		(-3.48)	(0.23)	(-2.32)
ratio squared		0.001**		0.003***	-0.000	0.001**
		(2.65)		(3.80)	(-0.05)	(2.77)
C2: Cumulative						
Prim. educ. ratio		-0.154*	-0.153*	-0.483***	0.050	0.072
		(-2.16)	(-2.14)	(-3.38)	(0.21)	(0.32)
ratio squared		0.001**	0.001**	0.003***	0.000	-0.000
		(2.65)	(2.63)	(3.68)	(0.04)	(-0.04)
C3: +rule of law						
Prim. educ. ratio	-0.369***	-0.392***	-0.395***	-0.679***	0.080	0.093
	(-3.71)	(-3.92)	(-3.99)	(-4.60)	(0.34)	(0.41)
ratio squared	0.002***	0.003***	0.003***	0.004***	-0.000	-0.000
	(4.16)	(4.41)	(4.48)	(5.07)	(-0.03)	(-0.07)

Note: Coefficients from ZINB estimation, t-statistics in parenthesis. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001. For missing entries the estimation process did not converge.

For the tertiary education enrolment ratio, shown in Table 16, estimation coefficients are all positive and often weakly significant. The positive coefficient can also be found for the linear specification without the quadratic term. Inspecting the data to understand this statistical result, one finds very high mean female/male enrolment ratios in small island developing countries (e.g. Bermuda 195%, Domenica 225%, Jamaica 215%, Puerto Rico 150%, Panama 152%). The authors reject the interpretation that a reduction in female tertiary education could reduce vulnerability. Rather an increase in male tertiary education seems warranted.

As a final variable for gender equality in education we look at the female/male enrolment ration in primary and secondary education as depicted in Table 17. Estimated coefficients are all negative, often significantly so at p <.1. This again indicates that more gender equality in primary or secondary education is negatively related to disaster fatalities or in other words, positively related to vulnerability.

Overall, there is some evidence that gender equality in education reduces vulnerability to extreme weather events. This is especially true for secondary education where we find consistent and statistical significant effects and to some degree for primary education. Tertiary education is a special case since it seems that especially in a number of developing countries, female participation in tertiary education far exceeds male participation. In order to understand what this means for gender equality in general and for tertiary education in particular, further study of this phenomenon is needed.

Table 16. Coefficients for female/male enrolment ratio tertiary education (*ratio_enroll_ tertiary*).

	est1	est2	est3	est4	est5	est6
		Share of urban pop	Democracy	Corruption perception	Gov. educ. expenditure	Ethnic frac.
C1: Individual						
Tert. educ. ratio	0.010*	0.012*	0.010*	0.013+	0.009	0.010*
	(2.00)	(2.43)	(1.99)	(1.78)	(1.33)	(2.07)
ratio squared	-0.000+	-0.000*	-0.000+	-0.000	-0.000	-0.000+
	(-1.72)	(-2.20)	(-1.72)	(-1.62)	(-0.84)	(-1.80)
C2: Cumulative						
Tert. educ. ratio	0.010*	0.012*	0.012*	0.017*	0.011	0.012
	(2.00)	(2.43)	(2.42)	(2.20)	(1.14)	(1.22)
ratio squared	-0.000+	-0.000*	-0.000*	-0.000*	-0.000	-0.000
	(-1.72)	(-2.20)	(-2.22)	(-2.22)	(-0.94)	(-0.99)
C3: +rule of law						
Tert. educ. ratio	0.004	0.008	0.007	0.015+	0.008	
	(0.68)	(1.21)	(1.07)	(1.77)	(0.73)	
ratio squared	-0.000	-0.000	-0.000	-0.000+	-0.000	
	(-0.47)	(-1.04)	(-1.03)	(-1.86)	(-0.73)	

Note: Coefficients from ZINB estimation, t-statistics in parenthesis. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001. For missing entries the estimation process did not converge.

Table 17. Coefficients for female/male enrolment ratio primary + secondary education (*ratio_prim_sec*).

	est1	est2	est3	est4	est5	est6
		Share of urban pop	Democracy	Corruption perception	Gov. educ. expenditure	Ethnic frac.
C1: Individual						
prim-sec ratio	-0.311***	-0.215**		-0.680***	-0.090	-0.320***
	(-4.18)	(-3.07)		(-5.27)	(-0.88)	(-4.07)
ratio squared	0.002***	0.001***		0.004***	0.001	0.002***
	(4.66)	(3.31)		(5.74)	(1.07)	(4.57)
C2: Cumulative						
prim-sec ratio	-0.311***	-0.215**	-0.168*	-0.471***	-0.471*	-0.392+
	(-4.18)	(-3.07)	(-2.34)	(-3.78)	(-2.16)	(-1.73)
ratio squared	0.002***	0.001***	0.001*	0.003***	0.003*	0.002*
	(4.66)	(3.31)	(2.46)	(4.00)	(2.42)	(2.01)
C3: +rule of law						
prim-sec ratio	-0.187*	-0.212*	-0.167+	-0.291**	-0.414+	-0.324
	(-2.33)	(-2.57)	(-1.91)	(-2.60)	(-1.79)	(-1.35)
ratio squared	0.001*	0.001**	0.001*	0.002**	0.003*	0.002+
	(2.51)	(2.79)	(2.03)	(2.83)	(2.09)	(1.66)

Note: Coefficients from ZINB estimation, t-statistics in parenthesis. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001. For missing entries the estimation process did not converge.

5.1.2 Female labour force participation

The estimation results for female labour force participation are shown in Table 18. All coefficients are negative and highly significant, indicating a strong statistical relation between more equal gender participation in the labour market and lower disaster fatalities.

Table 18. Coefficients for female labour force participation (% of total workforce, *female_lfp*).

	est1	est2	est3	est4	est5	est6
		Share of urban pop	Democracy	Corruption perception	Gov. educ. expenditure	Ethnic frac.
C1: Individual						
Female lfp	-0.054***	-0.044***	-0.054***	-0.033***	-0.048***	-0.047***
	(-7.24)	(-6.39)	(-7.34)	(-3.39)	(-5.94)	(-6.36)
C2: Cumulative						
Female lfp	-0.054***	-0.044***	-0.043***	-0.030**	-0.057***	-0.057***
	(-7.24)	(-6.39)	(-6.20)	(-3.25)	(-5.06)	(-5.03)
C3: +rule of law						
Female lfp	-0.044***	-0.044***	-0.044***	-0.046***	-0.062***	-0.061***
	(-5.34)	(-5.32)	(-5.31)	(-4.89)	(-4.98)	(-4.92)

Note: Coefficients from ZINB estimation, t-statistics in parenthesis. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001. For missing entries the estimation process did not converge.

If we allow for a non-linear relationship and include a squared term for female labour force participation, results indicate a counterintuitive positive, marginally decreasing relationship. This is probably related to the fact that in most countries women constitute by far less than 50% of the work force. In fact, the only countries where the mean share of women in the labour force is bigger than 50% is Burundi (51.7%), Cambodia (50.5%), Mozambique (54.8%), Rwanda (52%) and Sierra Leone (50.6%). The non-linear specification is accordingly rejected.

5.1.3 Gender rights and political participation

The share of female members of parliament is used as proxy for political participation of women. Women's political, economic and social rights are measured with by the CIRI variables discussed in some detail in Section 2.

The estimated coefficients for the share of female members of parliament are presented in Table 19. The majority of coefficients is significantly negative, indicating that a higher share of female members of parliament is associated with a lower death toll when disasters strike. However, six coefficients are insignificant and two of these even have a positive sign. This questions the robustness of these findings which will be put to scrutiny in the next section on robustness checks.

Table 19. Coefficients for share of female members of parliament (*female_mp*).

	est1	est2	est3	est4	est5	est6
		Share of urban pop	Democracy	Corruption perception	Gov. educ. expenditure	Ethnic frac.
C1: Individual						
Female MP	-0.036***	-0.029***	-0.036***	-0.010	-0.012+	-0.025***
	(-5.94)	(-5.02)	(-5.98)	(-1.43)	(-1.69)	(-3.76)
C2: Cumulative						
Female MP	-0.036***	-0.029***	-0.029***	-0.009	0.002	0.000
	(-5.94)	(-5.02)	(-4.87)	(-1.29)	(0.23)	(0.04)
C3: +rule of law						
Female MP	-0.023***	-0.023***	-0.023***	-0.022**	-0.005	-0.003
	(-3.53)	(-3.52)	(-3.53)	(-2.89)	(-0.58)	(-0.31)

Note: Coefficients from ZINB estimation, t-statistics in parenthesis. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001. For missing entries the estimation process did not converge.

The results for the variable measuring women politic rights is presented in Table 20. The variable is ordinal coded with values from zero to three and increasing values indication more political rights for women. The ordinal nature of the variable necessitates an indicator variable approach. The reference category is zero. For example, in estimation 1 (est1) of configuration 1 (C1), the first estimate indicates that in a country with wopol=1 the likelihood of more disaster fatalities as compared to wopol=0 significantly increases with p<.05. This is even more true if wopol=2. Also the coefficient for wopol=3 is positive, albeit insignificant. For wopol=1 and wopol=3 most coefficients are insignificant and often change their sign. The coefficients for wopol=2 though is consistently positive and mostly significant. This would imply that an increase in women's political rights, as measures by this CIRI variable, is associated with more disaster fatalities and thus more vulnerability. These results questions the fundamental hypothesis of this report that more equal societies are less vulnerable.

Table 20. Coefficients for women political rights (*wopol*).

	est1	est2	est3	est4	est5	est6
		Share of urban pop	Democracy	Corruption perception	Gov. educ. expenditure	Ethnic frac.
C1: Individual						
1.wopol	0.397*	0.227	0.358+	0.365	-0.435+	0.322+
	(2.16)	(1.27)	(1.87)	(1.27)	(-1.85)	(1.73)
2.wopol	1.160***	0.999***	1.135***	1.468***	0.316	0.802***
	(5.39)	(4.61)	(5.22)	(4.46)	(1.18)	(3.47)
3.wopol	0.094	0.336	0.043	1.323**	0.007	-0.226
	(0.31)	(1.11)	(0.14)	(3.26)	(0.02)	(-0.71)
C2: Cumulative						
1.wopol	0.397*	0.227	0.281	0.376	-0.093	-0.101
	(2.16)	(1.27)	(1.53)	(1.36)	(-0.28)	(-0.30)
2.wopol	1.160***	0.999***	1.026***	1.569***	0.828*	0.795*
	(5.39)	(4.61)	(4.70)	(4.81)	(2.04)	(1.96)
3.wopol	0.094	0.336	0.436	1.527***	0.589	0.542
	(0.31)	(1.11)	(1.41)	(3.86)	(1.29)	(1.18)

C3: +rule of law						
1.wopol	-0.200	-0.205	-0.091	0.207	0.044	0.038
	(-0.93)	(-0.95)	(-0.39)	(0.69)	(0.11)	(0.09)
2.wopol	1.625***	1.646***	1.749***	2.082***	0.992+	0.943+
	(6.34)	(6.44)	(6.56)	(6.20)	(1.90)	(1.81)
3.wopol	1.268***	1.237***	1.391***	1.733***	0.678	0.583
	(3.54)	(3.46)	(3.74)	(3.98)	(1.16)	(0.99)

Note: Coefficients from ZINB estimation, t-statistics in parenthesis. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001. For missing entries the estimation process did not converge.

However, as pointed out in the description of the data, there is very little variation in the CIRI variables and the coding process is vulnerable to bias. Also the robustness of these findings have to be considered (in Section 6).

Table 21 presents the coefficients for configuration 1 (C1) for women's social rights and women's economic rights. The coefficients for both variables exhibit a similar pattern as those for women's political rights with inconsistent results for right levels 1 and 3 but rather consistently positive effect for rights level 2. Since this pattern repeats itself for configuration 2 and 3 for both variables, for the sake of brevity these coefficients are not reported.

Table 21. Coefficients for configuration 1 (C1) women social right (*wosoc*) and women economic rights (*wecon*).

	est1	est2	est3	est4	est5	est6
		Share of urban pop	Democracy	Corruption perception	Gov. educ. expenditure	Ethnic frac.
Wosoc C1: Individual						
1.wosoc	0.397*	0.227	0.358+	0.365	-0.435+	0.322+
	(2.16)	(1.27)	(1.87)	(1.27)	(-1.85)	(1.73)
2.wosoc	1.160***	0.999***	1.135***	1.468***	0.316	0.802***
	(5.39)	(4.61)	(5.22)	(4.46)	(1.18)	(3.47)
3.wosoc	0.094	0.336	0.043	1.323**	0.007	-0.226
	(0.31)	(1.11)	(0.14)	(3.26)	(0.02)	(-0.71)
Wecon C1: Individual						
1.wecon	0.819***	0.624***		0.996***	0.011	0.539**
	(4.59)	(3.49)		(4.90)	(0.05)	(2.89)
2. wecon	1.356***	0.933***		1.824***	0.258	1.105***
	(7.03)	(4.53)		(7.71)	(1.07)	(5.41)
3. wecon	-0.028	-0.330		1.154***	-0.402	-0.210
	(-0.09)	(-1.09)		(3.44)	(-1.26)	(-0.70)

Note: Coefficients from ZINB estimation, t-statistics in parenthesis. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001. For missing entries the estimation process did not converge.

In summary, we find that if gender equality is approximated with measures of education, labour market or political participation, most estimates point to a negative relation between gender equality and vulnerability. Countries in which women participate more evenly in live face lower disaster fatalities in the face of climate related hazards. If,

alternatively, expert coded measures of women's rights are used, the results are more ambiguous and might even indicate that societies with more rights for women face more disaster fatalities and thus have higher vulnerability.

5.2 Income inequality

The income distribution is measured with the Gini coefficient of net and market incomes. The estimation coefficients of the Gini of net incomes are depicted in Table 22. All coefficients are significantly positive (p<.001). The same holds true for the Gini of market incomes. Respective estimation results are presented in Table 23, all estimated coefficients are positive and highly significant.

A higher Gini coefficient implies a higher income concentration. Accordingly, there is strong evidence that a more unequal distribution of incomes increases a country's vulnerability, i.e. increases the number of disaster fatalities.

Table 22. Coefficients for the Gini of net incomes (*gini_net*).

	est1	est2	est3	est4	est5	est6
		Share of urban pop	Democracy	Corruption perception	Gov. educ. expenditure	Ethnic frac.
C1: Individual						
Gini net	0.069***	0.050***	0.069***	0.063***	0.041***	0.069***
	(8.03)	(5.74)	(7.91)	(4.00)	(4.07)	(7.83)
C2: Cumulative						
Gini net	0.069***	0.050***	0.051***	0.053***	0.057***	0.057***
	(8.03)	(5.74)	(5.85)	(3.60)	(4.28)	(4.25)
C3: +rule of law						
Gini net	0.069***	0.071***	0.073***	0.101***	0.079***	0.079***
	(5.27)	(5.34)	(5.50)	(6.43)	(4.63)	(4.62)

Note: Coefficients from ZINB estimation, t-statistics in parenthesis. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001. For missing entries the estimation process did not converge.

Table 23. Coefficients for the Gini of market incomes (*gini_market*).

	est1	est2	est3	est4	est5	est6
		Share of urban pop	Democracy	Corruption perception	Gov. educ. expenditure	Ethnic frac.
C1: Individual						
Gini market	0.047***	0.038***	0.047***	0.055***	0.031**	0.041***
	(5.08)	(4.41)	(4.97)	(4.12)	(3.14)	(4.27)
C2: Cumulative						
Gini market	0.047***	0.038***	0.040***	0.055***	0.049***	0.051***
	(5.08)	(4.41)	(4.61)	(4.41)	(3.88)	(3.99)
C3: +rule of law						
Gini market	0.058***	0.058***	0.058***	0.074***	0.055***	0.056***
	(4.98)	(4.98)	(5.04)	(5.34)	(3.55)	(3.65)

Note: Coefficients from ZINB estimation, t-statistics in parenthesis. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001. For missing entries the estimation process did not converge.

So far gender equality and income distribution have been analysed separately. But social (in)equalities comprises both distributional aspects and thus will be considered jointly in the following subsection.

5.3 Social inequality: gender and income inequality

Table 24 depicts the estimation coefficients resulting from jointly including the Gini of net incomes and the female to male primary and secondary education enrolment ratio and its square in the specifications of the main set. The coefficient for Gini-net is significantly positive in all estimations. For the gender ratio in education participation again a u-shape relation emerges. Estimates are throughout negative and significant for half of the specifications. For configuration 3 (C3) the coefficients for education participation are all insignificant while the Gini of net incomes remains highly significant.

Table 24. Coefficients for the Gini of net incomes (*gini_net*) and female/male enrolment ration in primary and secondary education (*ratio_prim_sec*).

	est1	est2	est3	est4	est5	est6
		Share of urban pop	Democracy	Corruption perception	Gov. educ. expenditure	Ethnic frac.
C1: Individual						
Gini net	0.067***	0.054***	0.058***	0.067***	0.053***	0.065***
	(6.08)	(5.14)	(4.86)	(4.63)	(4.07)	(5.72)
Prime-sec ratio	-0.508***	-0.371***	-0.440***	-1.350***	-0.261	-0.566***
	(-4.06)	(-3.49)	(-3.45)	(-5.20)	(-1.59)	(-4.15)
Squared ratio	0.003***	0.002***	0.003***	0.008***	0.002+	0.003***
	(4.43)	(3.66)	(3.69)	(5.51)	(1.72)	(4.52)
C2: Cumulative						
Gini net	0.067***	0.054***	0.047***	0.041**	0.037*	0.038*
	(6.08)	(5.14)	(4.12)	(2.71)	(2.34)	(2.41)
Prime-sec ratio	-0.508***	-0.371***	-0.324**	-0.771**	-0.178	-0.195
	(-4.06)	(-3.49)	(-3.00)	(-2.83)	(-0.55)	(-0.60)
Squared ratio	0.003***	0.002***	0.002**	0.004**	0.001	0.001
	(4.43)	(3.66)	(3.08)	(2.96)	(0.74)	(0.79)
C3: +rule of law						
Gini net	0.054***	0.054***	0.041**	0.044**	0.049*	0.049*
	(3.81)	(3.76)	(2.64)	(2.59)	(2.46)	(2.47)
Prime-sec ratio	-0.261	-0.250	-0.232	-0.234	-0.051	-0.077
	(-1.48)	(-1.43)	(-1.35)	(-1.01)	(-0.17)	(-0.26)
Squared ratio	0.002+	0.002	0.001	0.001	0.001	0.001
	(1.69)	(1.62)	(1.47)	(1.18)	(0.45)	(0.54)

Note: Coefficients from ZINB estimation, t-statistics in parenthesis. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001. For missing entries the estimation process did not converge.

Results for female labour force participation and the Gini of net incomes are presented in Table 25. The estimates for both measures are significant throughout with the expected

positive sign for Gini net and negative sign for female labour force participation. A higher concentration of incomes significantly increases and a higher participation of women in the labour force significantly decreases total death from disasters. Given that these measures are a good approximation of social inequality, these are the strongest results so far indicating that more socially equal societies experience less fatalities when disasters strike, i.e. more equal societies are less vulnerable.

Table 25. Coefficients for the Gini of net incomes (*gini_net*) and the share of women in the labour force (*female_lfp*).

	est1	est2	est3	est4	est5	est6
		Share of urban pop	Democracy	Corruption perception	Gov. educ. expenditure	Ethnic frac.
C1: Individual						
Gini net	0.051***	0.037***	0.050***	0.042*	0.029**	0.054***
	(5.31)	(4.24)	(5.02)	(2.45)	(2.98)	(5.58)
Female lfp	-0.049***	-0.041***	-0.051***	-0.052**	-0.047***	-0.043***
	(-4.34)	(-4.23)	(-4.43)	(-2.73)	(-4.70)	(-3.85)
C2: Cumulative						
Gini net	0.051***	0.037***	0.039***	0.039**	0.041**	0.041**
	(5.31)	(4.24)	(4.34)	(2.62)	(2.99)	(2.97)
Female lfp	-0.049***	-0.041***	-0.039***	-0.047**	-0.056**	-0.056**
	(-4.34)	(-4.23)	(-4.02)	(-2.76)	(-3.13)	(-3.13)
C3: +rule of law						
Gini net	0.056***	0.057***	0.058***	0.070***	0.051**	0.051**
	(4.17)	(4.18)	(4.32)	(4.23)	(2.89)	(2.91)
Female lfp	-0.072***	-0.071***	-0.069***	-0.088***	-0.077***	-0.077***
	(-4.69)	(-4.64)	(-4.50)	(-4.49)	(-3.53)	(-3.55)

Note: Coefficients from ZINB estimation, t-statistics in parenthesis. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001. For missing entries the estimation process did not converge.

The final results of the main set presented in some detail are the coefficients from a joint estimation of female members of parliament and the Gini of net incomes, shown in Table 26. The coefficients for the income distribution are again positive and highly significant for all estimations. The estimation coefficient for *female_mp* is negative for all but two specifications. They are statistically significant for configuration 3 (C3) and specification 5 and 6 (est5, est6) of configuration 2. Results for C3 could imply that there is some important interdependency between the rule of law and female political participation. For example it could be hypothesized that more equal gender rights in politics can only reduce vulnerability in societies where the rule of law is effectively implemented. Since the *female_mp* coefficients are also significant for the most extensive specification of C2 also a sample effect is a valid explanation: the share of female members of parliament is significantly related to total disaster fatalities in the subset of countries with most extensive data coverage.

The estimation results for the combination of Gini net with female-male enrolment ratios for primary, secondary and tertiary education in general confirm the results. The coefficients for the Gini of net incomes are consistently significantly positive. And the coefficients for the enrolment ratios are qualitatively similar to those estimates obtained from individual estimation. The same hold true for Gini net estimated with the different CIRI variables on women's rights. Gini-net-coefficients are consistently significantly positive and women's rights have rather ambiguous results.

Table 26. Coefficients for the Gini of net incomes (*gini_net*) and the female share of members of parliament (*female_mp*).

	est1	est2	est3	est4	est5	est6
		Share of urban pop	Democracy	Corruption perception	Gov. educ. expenditure	Ethnic frac.
C1: Individual						
gini_net	0.113***	0.087***	0.112***	0.068***	0.056***	0.111***
	(9.89)	(7.40)	(9.88)	(3.87)	(4.69)	(9.49)
female_mp	-0.004	-0.018+	-0.004	0.013	-0.012	0.002
	(-0.43)	(-1.83)	(-0.43)	(1.11)	(-1.27)	(0.16)
C2: Cumulative						
gini_net	0.113***	0.087***	0.085***	0.056***	0.051***	0.049***
	(9.89)	(7.40)	(7.35)	(3.39)	(3.51)	(3.36)
female_mp	-0.004	-0.018+	-0.019+	-0.001	-0.028*	-0.029*
	(-0.43)	(-1.83)	(-1.92)	(-0.10)	(-2.44)	(-2.48)
C3: +rule of law						
gini_net	0.085***	0.084***	0.087***	0.106***	0.066***	0.065***
	(5.86)	(5.78)	(6.11)	(6.47)	(3.63)	(3.54)
female_mp	-0.026*	-0.027*	-0.030**	-0.034**	-0.033*	-0.033*
	(-2.35)	(-2.37)	(-2.59)	(-2.69)	(-2.56)	(-2.51)

Note: Coefficients from ZINB estimation, t-statistics in parenthesis. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001. For missing entries the estimation process did not converge.

If the distribution of market incomes is used instead of the distribution of net incomes, results are qualitatively unchanged. The significance levels are a bit lower is some instances, but estimated coefficients are positive throughout.

In our reading, this results provide some evidence that the distribution of income and equal participation of men and women in society as expression of gender equality are both important determinants of a societies vulnerability to extreme weather events and thus ultimately their resilience.

For the distribution of incomes, the measurement of which is comparatively unproblematic, this holds in general. For gender equality, this interpretation might need qualification, contingent on what variables are considered suitable proxies. For some measures of gender equality the evidence is ambiguous in the sense that estimated coefficients are insignificant or even have the wrong sign. This is especially the case for the CIRI measures of women's rights. Respective estimation results seem to indicate that more rights for women increase disaster fatalities. In order to evaluate these counter-intuitive results and assure robustness of the more intuitive findings, attention is now directed toward some extensive robustness tests.

6. Robustness Checks

The results laid out in the last chapter are derived from specifications which are based on sound arguments but which are still somewhat arbitrary. Should the dependent variable, counting the total death toll, be included in levels (as done so far) or in logs? Should the controls for the area, the population and the per capita GDP be included in logs (as done so far) or in levels? Should year effects be included in the explanation of fatalities or in the explanation of zeros in the first step or not at all? Do the results hold up for a sample of high or low income countries only? Is the prevalence of poverty maybe more important than the distribution and concentration of incomes?

To answer these questions a series of robustness checks are performed by adding or changing features of the main set. The respective change is undertaken for the whole set and all eighteen modified specifications are re-estimated. After shortly explaining the applied modifications the results will be presented in a highly aggregated fashion. It will especially be pointed out if and when a modification qualitatively changes the estimation coefficients as compared to the main set so that the conclusions of the result section have to be reassessed.

As a first step the specifications in the main set are modified so as to account for clustering at the country level (1), i.e. correlation among observations of a given county. Thus we obtain robust standard errors which are considerable higher than non-robust standard errors. Alternatively, we include year dummies in the second step estimation (2) to account for all unobserved year-specific variation. As a third modification the permanent control variables area, population and per capita GDP are included in levels and not in logs (3). In a fourth step the main set is used in its original specification but only on subsets of counties. Results are estimated for three different samples: OECD + non-OECD high income countries (4), high middle income countries (5) and low and low middle income countries (6).

Then the question whether the poverty rate rather than the income distribution might be a driving force is examined. The WDI data contains poverty data only for a subset of counties and years. For these countries also a Gini coefficient of the income distribution is available (*gini_wb*). To account for possible sample selection effects all specifications from the main set are estimated on this reduced sample with available poverty data (7), the World Bank sample. To assure robustness of the results with respect to the income distribution, the Gini of net incomes (*gini_net*) in the main set is substituted with the Gini coefficient provided by the World Bank (*gini_wb*) (8). To understand the effect of poverty, a measure of the poverty-gap (*poverty*) is added to all specifications containing a measure of the income distribution (9). This exercise is repeated using the poverty head count ratio (*poverty_ratio*) instead (10).

So far the first step selection function explaining the zero observation of death counts only included the number of occurrences of the different disasters. To assure that results are not driven by the choice of the selection function the log of per capita GDP (11), the country area (12) and the latitude of a countries capital (13) are included in turn.

A final robustness check concerns the specification of the dependent variable. So far the count of disaster fatalities has been included in levels. While there is no obvious argument why the dependent variables should be included in logs, there are examples in the literature where it is done so (Kahn 2005). Accordingly, the main set is re-estimated using the log of total disaster death plus one (14).[15] This modified version of the main set is then again estimated with standard errors robust to clustering at the country level (15) and with year fixed effects (16).

[15] Since the log of zero is not defined, one additional fatality is added to all observations.

The following tables show aggregate results for all this robustness tests. No formal aggregation procedure has been employed to aggregate the eighteen estimation results underlying each set. The algebraic sign and the stars indicate the tendency and in some cases bandwidth of obtained estimation results. In case of multiple signs, the first sign is in general the more common one within the estimated set.

The second line of each cell compares how the aggregated results from each respective set compare to the results obtained from the main set (summarized in line three of each table). The employed tokens mean:

(√) similar or better results than main set

(℞) worse results than main set but basic hypothesis not challenged

(†) results potentially could challenge basic hypothesis

The basic hypothesis referred to and the benchmark of valuation is the hypothesis that more equal societies have fewer disaster fatalities. In this sense "better" results imply stronger empirical evidence for the basic hypothesis than provided by the estimations in the main set.

In Table 27 the robustness checks for equality in female labour market and education participation are summarized. For tertiary education the hypothesis was rejected already in the main set, a conclusion not changed by the robustness tests. Estimates for primary enrolment ratios remain ambiguous, those for enrolment ratios in secondary education remain strong. There is however some indication that in middle income countries equality in education enrolment is not important for vulnerability (see (5)). Results for female labour force participation are robust to most modifications. (Only the rather small sample for middle income countries and the formulation with log-dependent variable and year dummies question the negative statistical relation between more gender equality in labour market participation and lower disaster fatalities.)

Table 27. Robustness checks, female labour market and education participation.

	enrolment ratio primary	enrolment ratio secondary	enrolment ratio tertiary	enrolment ratio prim. & sec.	Female lfp
Main Set	-*/+	-***	+	-**	-***
+ clustering at country level (1)	+/- (℞)	-**/- (℞)	+ (√)	-*/- (℞)	-* (℞)
+ year dummies (2)	+*/- (†)	-***, +/- (℞)	+ (√)	- (℞)	-***/- (℞)
non-log area, population, pc-gdp (3)	-***/+ (℞)	-***/- (℞)	-***/+** (√,℞)	-***/- (√)	-*** (√)
Sub-samples					
High income sample (4)	- (√)	-***, +/- (℞)	- (√)	-***,+ (℞)	-*** (√)
Middle income sample (5)	+ (†)	+ (†)	- (√)	+/- (℞)	-/+ (†)
Low income sample (6)	-*** (√)	-*** (√)	-, +/- (√)	-** (√)	-*** (√)
World Bank Sample (7)	-* (√)	-***/- (℞)	+** (†)	-** (√)	-*** (√)
gini-wb (8)	X	X	X	-*** (√)	-*** (√)
+ poverty gap (9)	X	X	X	X	X

+ poverty head count ratio (10)	X	X	X	X	X
modified selection function					
+ log pc GDP (11)	-***/+ (√)	-** (ℱ)	+ (√)	-*** (√)	-*** (√)
+ area (12)	-***/+ (√)	-*** (√)	+*/+ (†)	-*** (√)	-*** (√)
+ latitude (13)	-***/+ (√)	-*** (√)	+*/+ (†)	-*** (√)	-*** (√)
log(totdeath+1) (14)	+/- (ℱ)	-*, +/- (ℱ)	+ (√)	-/+ (ℱ)	-** (ℱ)
+ clustering at country level (15)	+/- (ℱ)	-*, +/- (ℱ)	+ (√)	-/+ (ℱ)	-** (ℱ)
+ year dummies (16)	+/- (ℱ)	-*, +/- (ℱ)	+ (√)	-/+ (ℱ)	-**, + (†)

Table 28 depicts the overview over robustness checks for women's rights and political participation. The results from the CIRI variables have been ambiguous or even opposing the basic hypothesis. For women's political rights robustness checks produce very ambiguous results, so that we conclude that there is no statistical evidence in this variable. For women's social rights many robustness results oppose the basic hypothesis. If however the dependent variable is used in logs (14, 15, 16), results are in line with the basic hypothesis. The robustness results for women's economic rights are in general more supportive of the basic hypothesis than the results from the main set. Still, there is a lot of ambiguity. Finally, for the share of female members of parliament the basic hypothesis is generally supported with some ambiguity. This provides some evidence for the importance of equality in political participation for vulnerability.

In Table 29 the robustness checks of the individual effects of the income distribution are show. The results for both, the Gini of net and the Gini of market incomes are robust and provide strong evidence for a positive effect of more equality on less disaster fatalities and accordingly less vulnerability, throughout.

Table 28. Robustness checks, female political participation and women's rights.

	female_mp	wopol	wosoc	wecon
Main Set	-***, +	+*, -	+*, -	+*, -
+ clustering at country level (1)	-* (√)	+/- (√)	+/- (√)	+/- (√)
+ year dummies (2)	-*, + (ℱ)	+/- (√)	+/-, -* (√)	-* (√)
non-log area, population, pc-gdp (3)	-*** (√)	-*, + (√)	-***, + (√)	-** (√)
Sub-samples				
High income sample (4)	-*** (√)	+/- (√)	+/-, -* (√)	-* (√)
Middle income sample (5)	-/+ (ℱ)	+/- (√)	+/- (√)	- (√)
Low income sample (6)	-*/+ (ℱ)	-* (√)	+ (†)	+ (†)

World Bank Sample (7)	-*** (√)	+/- (√)	+* (†)	+*, -* (√)
gini-wb (8)	-*** (√)	X	+** (†)	+*, - (√)
+ poverty gap (9)	X	X	X	X
+ poverty head count ratio (10)	X	X	X	X
modified selection function				
+ log pc GDP (11)	-***, + (√)	+ (√)	+*, -/+ (†)	-**, +* (√)
+ area (12)	-***, + (√)	+*, -* (℞)	+*, -/+ (†)	-*, +* (√)
+ latitude (13)	-***, + (√)	+*, -* (℞)	+*, -/+ (†)	-*, +* (√)
log(totdeath+1) (14)	-*, + (℞)	+/- (℞)	-**, + (√)	- (√)
+ clustering at country level (15)	- (√)	-*, + (√)	-*, + (√)	-* (√)
+ year dummies (16)	-, + (℞)	-*, + (√)	-* (√)	- (p<.1) (√)

Table 29. Robustness checks, income distribution.

	Gini of net incomes	Gini of Gross incomes
Main Set	+***	+***
+ clustering at country level (1)	+* (℞)	+* (℞)
+ year dummies (2)	+** (℞)	+*, + (℞)
non-log area, population, pc-gdp (3)	+*, - (℞)	-*, +*
Sub-samples		
High income sample (4)	+***, - (℞)	+/- (℞)
Middle income sample (5)	+* (℞)	+**, - (†)
Low income sample (6)	+*** (√)	+**, + (℞)
World Bank Sample (7)	+*** (√)	+** (℞)
gini-wb (8)	X	X
+ poverty gap (9)	+*** (√)	+*** (√)
+ poverty head count ratio (10)	+*** (√)	+*** (√)
modified selection function		

+ log pc GDP (11)	+*** (√)	+*** (√)
+ area (12)	+*** (√)	+*** (√)
+ latitude (13)	+*** (√)	+*** (√)
log(totdeath+1) (14)	+*** (√)	+* (℞)
+ clustering at country level (15)	+** (℞)	+* (℞)
+ year dummies (16)	+*** (√)	+* (℞)

The final two tables, Table 30 and Table 31, contain robustness checks for social inequality, i.e. the joint estimation of the effect of gender equality and the income distribution. Checking the robustness for income inequality and female education participation (*ratio_prim_sec*), i.e. social inequality I, results for the effect of the income distribution are confirmed in almost all cases. Also the conclusion for female education participation finds mostly support. Only for middle income countries and the use of the dependent variable in logs results are ambiguous. Looking at social inequality II (income distribution and female labour market participation), results for Gini net are by and large robust. Similarly to social inequality I, the effect of the

Table 30. Robustness checks, social inequality I, II.

	Social inequality I		Social inequality II	
	Gini net	Ratio prim. sec.	Gini net	Female lfp
Main Set	+***	-***, -	+**	-**
+ clustering at country level (1)	+* (℞)	- (℞)	+* (℞)	-* (℞)
+ year dummies (2)	+*** (√)	+/- (℞)	+** (√)	-***, - (℞)
non-log area, population, pc-gdp (3)	+***, - (†)	-***, - (√)	+***, - (†)	-*** (√)
Sub-samples				
High income sample (4)	+*, - (†)	+/- (℞)	+/-, -* (†)	-*** (√)
Middle income sample (5)	+* (℞)	+, - (†)	+** (√)	-*, +/- (℞)
Low income sample (6)	+** (℞)	- (℞)	+**, - (†)	-** (√)
World Bank Sample (7)	X	X	X	X
gini-wb (8)	+** (gini-wb)	X	+*** (gini-wb)	X
+ poverty gap (9)	+*** (gini-wb)	X	+** (gini-wb)	X
+ poverty head count ratio (10)	+***, + (gini-wb)	X	+*** (gini-wb)	X

modified selection function				
+ log pc GDP (11)	+*** (√)	-***, - (√)	+*** (√)	-*** (√)
+ area (12)	+*** (√)	-***, - (√)	+*** (√)	-*** (√)
+ latitude (13)	+*** (√)	-***, - (√)	+*** (√)	-*** (√)
log(totdeath+1) (14)	+* (ℱ)	-/+ (†)	+*** (√)	- (ℱ)
+ clustering at country level (15)	+* (ℱ)	-/+ (†)	+** (√)	- (ℱ)
+ year dummies (16)	+** (ℱ)	+/- (†)	+*** (√)	- (ℱ)

income distribution is ambiguous only in high-income countries. Robustness results for female labour force participation are sometimes a bit weaker than in the main set but never question the conclusion drawn and thus overall provide considerable evidence for the basic hypothesis. For social inequality III, summarized in Table 31, the results for the income distribution are reaffirmed. The evidence for the share of female members of parliament, which was ambiguous already in the main set, is not considerably strengthened by the robustness exercise. Four out of twelve estimation

Table 31. Robustness checks, social inequality III, IV

	Social inequality III		Social inequality IV	
	Gini net	Female MP	Gini net	wecon
Main Set	+***	-*, +	+***	+*, -*
+ clustering at country level (1)	+*** (√)	+/- (†)	+* (ℱ)	-*, +/- (√)
+ year dummies (2)	+*** (√)	+/- (†)	+*, - (†)	+*, -* (√)
non-log area, population, pc-gdp (3)	+*** (√)	-**, + (√)	+*** (√)	-** (√)
Sub-samples				
High income sample (4)	+***, - (†)	- (√)	+***, - (†)	+/- (ℱ)
Middle income sample (5)	+*** (√)	-**, + (√)	+*** (√)	+/- (ℱ)
Low income sample (6)	+*** (√)	+/- (†)	-, + (†)	+/- (ℱ)
World Bank Sample (7)	X	X	X	X
gini-wb (8)	+** (gini-wb)	X	+*** (gini-wb)	X
+ poverty gap (9)	+*** (gini-wb)	X	+** (gini-wb)	X
+ poverty head count ratio (10)	+***, + (gini-wb)	X	+*** (gini-wb)	X

modified selection function				
+ log pc GDP (11)	+*** (√)	-*, + (√)	+*** (√)	+*, -* (√)
+ area (12)	+*** (√)	-*, + (√)	+*** (√)	+*, -* (√)
+ latitude (13)	+*** (√)	+/- (†)	+*** (√)	+*, -* (√)
log(totdeath+1) (14)	+** (ℳ)	-*, + (√)	+*** (√)	-*,+ (√)
+ clustering at country level (15)	+**, + (ℳ)	-, + (ℳ)	+** (ℳ)	- (√)
+ year dummies (16)	+*** (√)	-/+ (ℳ)	+** (ℳ)	-*, + (√)

sets cast doubt on the basic hypothesis. In the context of social inequality there is thus only weak evidence that equal gender participation in the political arena is a driving factor of vulnerability. In the context of social inequality IV the effect of the income distribution is mostly robust. For high income and low income countries as well as for the estimation set with year dummies a few results opposing the basic hypothesis are obtained. The robustness test for women's economic rights are in general more positive than the main results. However, overall results are highly ambiguous and do not provide evidence that gender equality as measured by this variable has a significant effect on disaster fatalities and vulnerability.

7. Conclusion

This technical report will now be concluded by first summarizing the main results from the empirical exercise. Then a number of caveats related to the quantitative analysis will be discusses. Thirdly, there will be some reflections on mechanism that could account for observed empirical phenomena and related open questions inviting future research.

7.1 Summary of results

While the measurement of the distribution of incomes is a non-trivial task, income inequality is conceptually rather well defined. In contrast, there are a considerable number of conceptual problems associated with the measurement of gender equality. In the present study gender equality and the (in-) equality of the distribution of incomes are defined as jointly determining social inequality. The multiplicity of empirical proxies for gender equality and a wide variety of estimation results contingent on the specific variable used, make a very concise summary of results difficult.

There is unequivocal, strong evidence of a significant statistical relation between lower fatalities from climate related disasters and more equality for the distribution of income, female labour force participation and female participation in secondary education. This holds true independent whether only gender equality, equality of the income distribution or a combination of both are considered.

For female participation in primary education and the share of female members of parliament there is some indication of a statistical relation between more gender equality and lower numbers of disaster fatalities. This is also true if analysed jointly with the distribution of incomes, for which the effect is always observable.

For women's political, social and economic rights, captured by expert-coded, ordinal variables provided in the CIRI dataset no consistent effect can be isolated. A considerable number of estimates even indicate that more extensive rights for women increase the probability of more disaster fatalities. This finding however is not robust to specification and sample modifications. The same is true for female participation in tertiary education, there are also a number of positive and many ambiguous estimates. Why gender inequality in tertiary education does not contribute to vulnerability in the same way as secondary education does, remains an open question in need of further research. The results obtained for women's rights as captured in the CIRI variables however are rejected by the authors. These results might be driven by coding choices and a lack of variability in the data.

7.2 Caveats of the quantitative analysis

The analysis has produced a number of clear cut results which can be used for policy recommendations. However, there are a number of caveats that have to be taken into account when interpreting this results (as with most empirical findings in economics). Problems arise form data quality, the chosen macro perspective, the challenge to establish causation and specification search.

The question of what constitutes the proper empirical model and the search for the correct specification are central methodological problems in econometrics. Underlying assumptions, test statistics and goodness of fit measures provide some guidance, especially for the selection of the appropriate estimation method. There is however no method for determining the appropriate set of control variables and specification selection seems to be a wide-spread phenomenon, also in the top peer-reviewed journals (Brodeur et al. 2013). We employed a multiple specification approach and extensive robustness checks to make the issue of specification choice transparent. At the

same time these multiple estimates showed how strongly estimation coefficients of interest can depend on the choice of control variables.

It is also important to keep in mind that the present analysis can only establish statistical relations and does not provide proof of an underlying causal relationship. In addition there are a number of endogeneity issues which are not addressed explicitly: The log of per capita GDP in PPP is included in all specifications since socio-economic development is an established and important determinant of vulnerability. At the same time female empowerment and increasing gender equality are strongly related to the level of development, albeit the direction of the causal link is debated (e.g. Doepke et al. 2012, Duflo 2011, Fernández 2014). Accordingly, the estimates for gender equality might suffer from endogeneity bias. The fact that the occurrence of a climate related extreme weather event can potentially have an influence on the distribution of income and wealth (Miljkovic and Miljkovic 2014, Park et al. 2015) provides a second potential source of endogeneity.

The choice of countries as units of observations entails further problems. Countries can entail considerable variability in the geographical distribution of income concentration and vulnerability. Since extreme weather events are often events at the local level, a lot of within-subject heterogeneity is not used. A more detailed understanding of the phenomenon at hand is difficult since a lot of interactions might be averaged out.

Finally the data quality has to be considered. Potential and actual shortcomings of the data have been exhaustively discussed in Section 2. Possibly systematic bias in the disaster data is mitigated by some robustness checks, especially separate estimations for different country groups sorted by income. For a lack of variability and the probability of biased coding in the CIRI data there is however little remedy. On top of that there is the general problem that countries might strategically falsify their economic data. Michalski and Stolz (2013) provide evidence for that. Since the data selection for this study followed the peer-reviewed academic literature, data problems can be considered near universal and should be borne in mind.

7.3 Possible explanations and future research

The present study shows that some forms of inequality have an influence on vulnerability and resilience of countries. To establish this relation the problematic question of quantifying vulnerability or resilience is sidestepped by looking at disaster fatalities, arguably the most negative result from extreme weather events in the context of too much vulnerability or too little resilience. We argue that a statistical relation between more gender and/or income equality associated with a reduction in the probability of high numbers of disaster fatalities provide indirect evidence for a reduction in vulnerability. But what is the underlying mechanism, i.e. why should inequality increase vulnerability or decrease system resilience?[16]

We propose a sketch of a theory for this relation. However, the mechanisms proposed need further elaboration and more empirical scrutiny in future research.

A high capacity to cope increases a country's resilience and decreases its vulnerability. The capacity to cope in turn depends on (or is produced with) a number of inputs, most notably available resources, good institutions and high levels of social cooperation.[17] Some, maybe most of the resources used will be public goods or have similar

[16] The link between vulnerability and poverty is obvious. But more inequality does not necessarily mean more poverty. A high (low) concentration of incomes does not always entail more (less) poverty, especially if poverty is measured in absolute terms.

[17] These inputs are certainly co-dependent: good institutions might allow for more widespread cooperation and trust and all of these together will foster development, thereby increasing available resources.

characteristics (e.g. sea wall, electricity grid, participation in vaccination). The provision of public goods entails a social dilemma in the sense that individual rational behaviour results in free riding and an under-provision of the public good while mutual cooperation would result in a better outcome for (almost) everybody. Cooperation in this sense is a successful solution for a social dilemma.

The propensity and ability to cooperate is directly influenced by the distribution of resources (income and wealth) among individuals. The literature however is rather ambiguous about the direct effect of inequality on cooperation. Especially theoretical contributions predict more contribution in situations of more unequally distributed endowments (Bergstrom et al. 1986, Chan et al. 1996). Experiments however often find the inverse effect of lower levels of cooperation under more concentrated distributions of endowments (Anderson et al. 2008, Cardenas 2003, Cardenas 2007, Cherry et al. 2005, Tavoni et al. 2011, Gaechter et al. 2014). The net effect of inequality seems to depend on a number of other factors (Chan et al. 1999).

But there is also an indirect effect of inequality on cooperation. Higher levels of wealth and income inequality make people more dissimilar and less trusting (Gustavsson and Jordahl 2008, Leigh 2006). Trust is thus an important determinant of cooperation and lower levels of trust due to more inequality result in lower levels of cooperation (Balliet and Van Lange 2013). Less cooperation reduces resilience and the capacity to cope directly and indirectly via a lower provision of public goods.

In the case of gender equality the direct effects of inequality on trust and cooperation might be less pronounced but could in principle also be present. If more gender equality implies that women have more decision power in society, then higher levels of cooperation could in addition follow from a generic gender effect. Women are shown to be less competitive and have a higher propensity to cooperate than men in some circumstances (Niederle and Vesterlund 2011, Balliet et al. 2011). Under conditions of more gender equality this might contribute to higher levels of cooperation throughout society. Finally, women empowerment is known to be strongly related to socio-economic development (Doepke et al. 2012, Duflo 2011, Fernández 2014). While we are controlling for per capita GDP, women empowerment might foster other components of socio-economic development which are important for a reduction in vulnerability and not captured by per capita GDP.

A detailed understanding of how gender equality and the income distribution affect vulnerability is left for future research.

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Appendix

Table A1. Variable Description, CIRI variable on women rights.

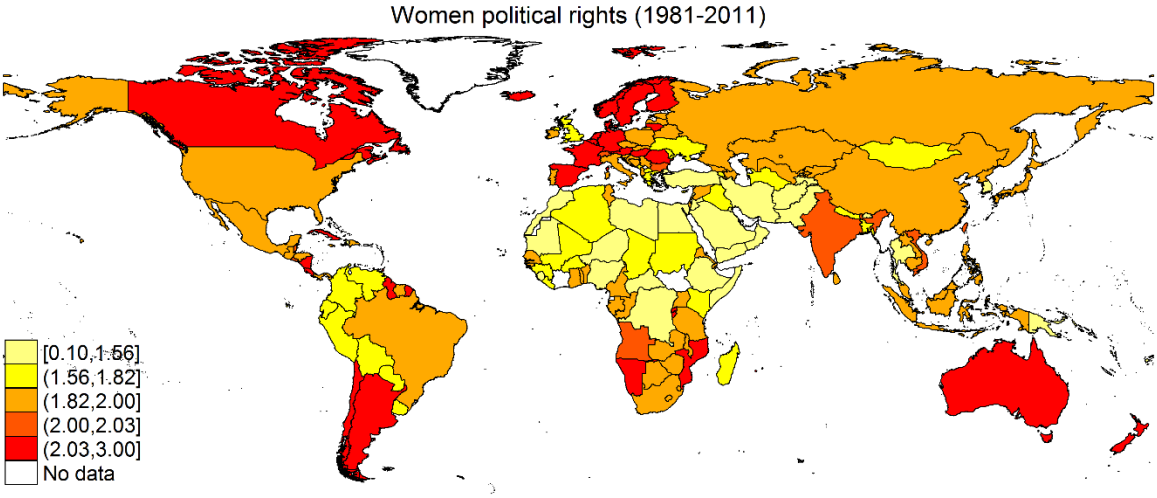
Variable (*variable name*)	Rights entailed	Coding
Women political rights (*wopol*)	the right to vote, the right to run for political office, the right to hold elected and appointed government positions, the right to join political parties, the right to petition government officials	(0) There are no X* rights for women under law and systematic discrimination based on sex may be built into the law. The gov. tolerates a high level of discrimination against women. (1) There are some X* rights for women under law. However, in practice, the gov. DOES NOT enforce these laws effectively or enforcement of laws is weak. The gov. tolerates a moderate level of discrimination against women. (2) There are some X* rights for women under law. In practice, the gov. DOES enforce these laws effectively. However, the gov. still tolerates a low level of discrimination against women. (3) All or nearly all of women's X* rights are guaranteed by law. In practice, the gov. fully and vigorously enforces these laws. The gov. tolerates none of almost no discrimination against women. * X stands for political, economic or social
Women economic rights (*wecon*)	equal pay for equal work, free choice of profession or employment without the need to obtain a husband or male relative's consent, the right to gainful employment without the need to obtain a husband or male relative's consent, equality in hiring and promotion practices, job security (maternity leave, unemployment benefits, no arbitrary firing or layoffs, etc...), non-discrimination by employers, the right to be free from sexual harassment in the workplace, the right to work at night, the right to work in occupations classified as dangerous, the right to work in the military and the police force	
Women social rights (*wosoc*)	the right to equal inheritance, the right to enter into marriage on a basis of equality with men, the right to travel abroad, the right to obtain a passport, the right to confer citizenship to children or a husband, the right to initiate a divorce, the right to own, acquire, manage, and retain property brought into marriage, the right to participate in social, cultural, and community activities, the right to an education, the freedom to choose a residence/domicile, freedom from female genital mutilation (FGM) of children and of adults without their consent, freedom from forced sterilization	

Table A2. List of countries in the sample.

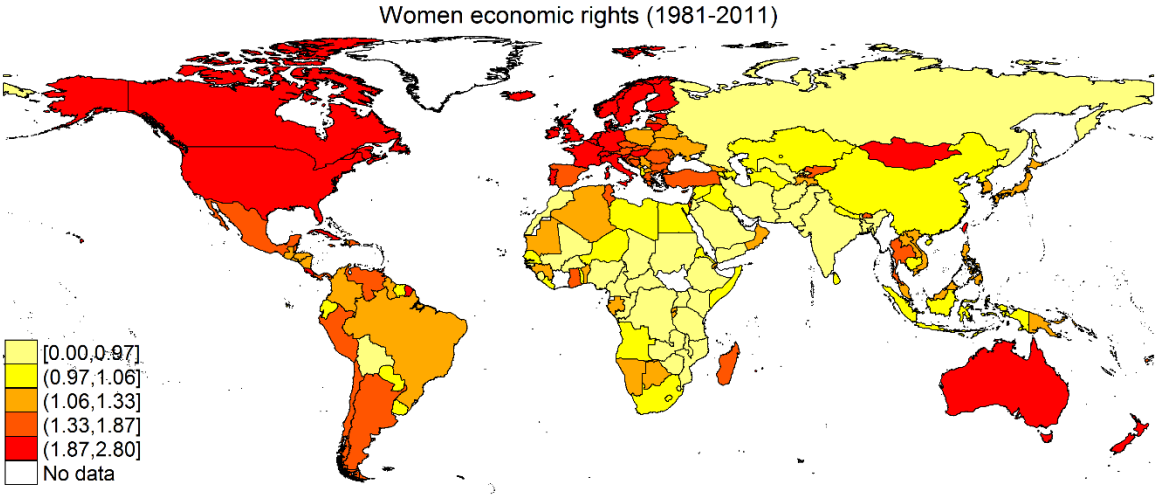
Country name			
	Dominican Rep.	Libya	Vincent & the Grenadine
Afghanistan	Ecuador	Lithuania	Samoa
Albania	Egypt	Luxembourg	Sao Tome and Principe
Algeria	El Salvador	Macau	Saudi Arabia
American Samoa	Eritrea	Macedonia	Senegal
Angola	Estonia	Madagascar	Serbia
Anguilla	Ethiopia	Malawi	Seychelles
Antigua & Barbuda	Fiji	Malaysia	Sierra Leone
Argentina	Finland	Maldives	Slovakia
Armenia	France	Mali	Slovenia
Australia	French Guiana	Marshall Islands	Solomon Islands
Austria	French Polynesia	Martinique	Somalia
Azerbaijan	Gabon	Mauritania	South Africa
Bahamas	Gambia	Mauritius	South Sudan
Bangladesh	Georgia	Mexico	Spain
Barbados	Germany	Micronesia	Sri Lanka
Belarus	Ghana	Moldova	Sudan
Belgium	Greece	Mongolia	Suriname
Belize	Grenada	Montenegro	Swaziland
Benin	Guadeloupe	Montserrat	Sweden
Bermuda	Guam	Morocco	Switzerland
Bhutan	Guatemala	Mozambique	Syria
Bolivia	Guinea	Namibia	Taiwan
Bosnia & Herzegovina	Guinea-Bissau	Nepal	Tajikistan
Botswana	Guyana	Netherlands	Tanzania
Brazil	Haiti	New Caledonia	Thailand
Bulgaria	Honduras	New Zealand	Timor-Leste
Burkina Faso	Hong Kong	Nicaragua	Togo
Burundi	Hungary	Niger	Tokelau
Cambodia	Iceland	Nigeria	Tonga
Cameroon	India	Niue	Trinidad & Tobago
Canada	Indonesia	North. Mariana Isl.	Tunisia
Cape Verde	Iran	Norway	Turkey
Cayman Islands	Iraq	Oman	Turkmenistan
Central African Rep.	Ireland	Pakistan	Turks and Caicos Islands
Chad	Israel	Palau	Tuvalu
Chile	Italy	Palestine	Uganda
China	Jamaica	Panama	Ukraine
Colombia	Japan	Papua New Guinea	United Kingdom
Comoros	Jordan	Paraguay	United States of America
Congo (Brazzaville)	Kazakhstan	Peru	Uruguay
Congo (Kinshasa)	Kenya	Philippines	Uzbekistan
Cook Islands	Kiribati	Poland	Vanuatu

Costa Rica	Korea, North	Portugal	Venezuela
Cote d'Ivoire	Korea, South	Puerto Rico	Vietnam
Croatia	Kuwait	Reunion	Virgin Islands, Bri.
Cuba	Kyrgyzstan	Romania	Virgin Islands, U.S.
Cyprus	Laos	Russian Federation	Wallis & Futuna Isl.
Czech Republic	Latvia	Rwanda	Yemen
Denmark	Lebanon	Saint Helena	Zambia
Djibouti	Lesotho	Saint Kitts & Nevis	Zimbabwe
Dominica	Liberia	Saint Lucia	

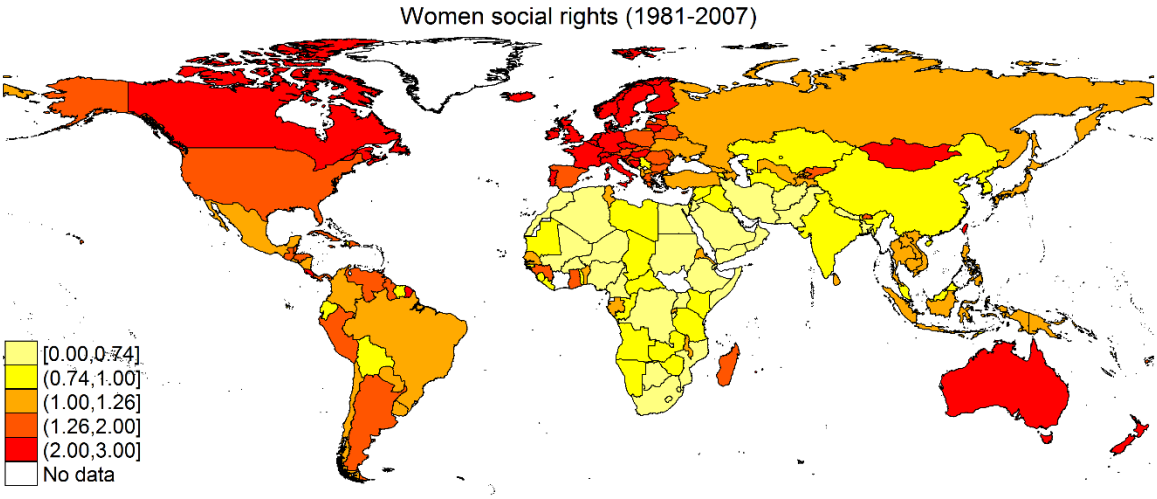
Map A1. Women political rights (averaged over 1981-2011).



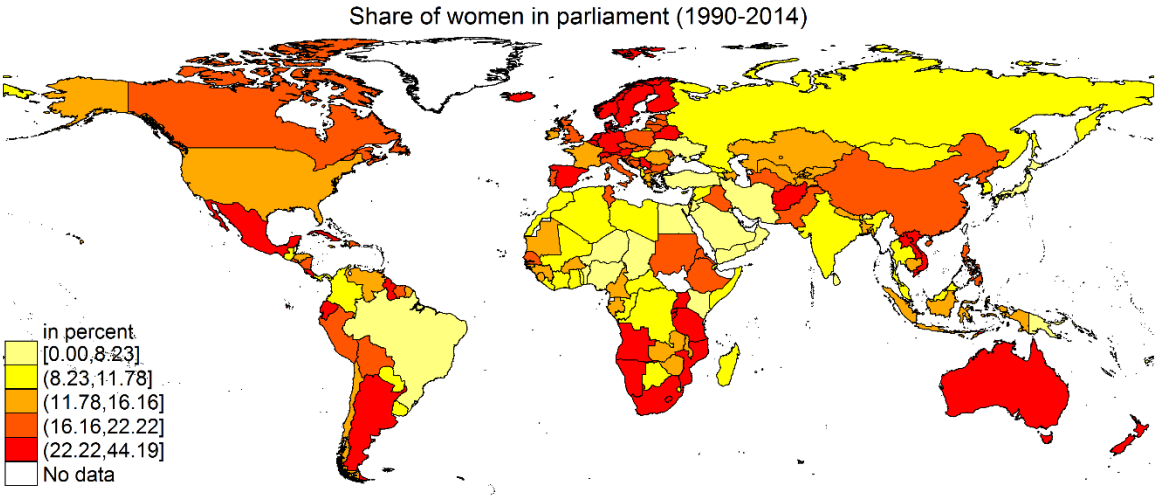
Map A2. Women political rights (averaged over 1981-2011).



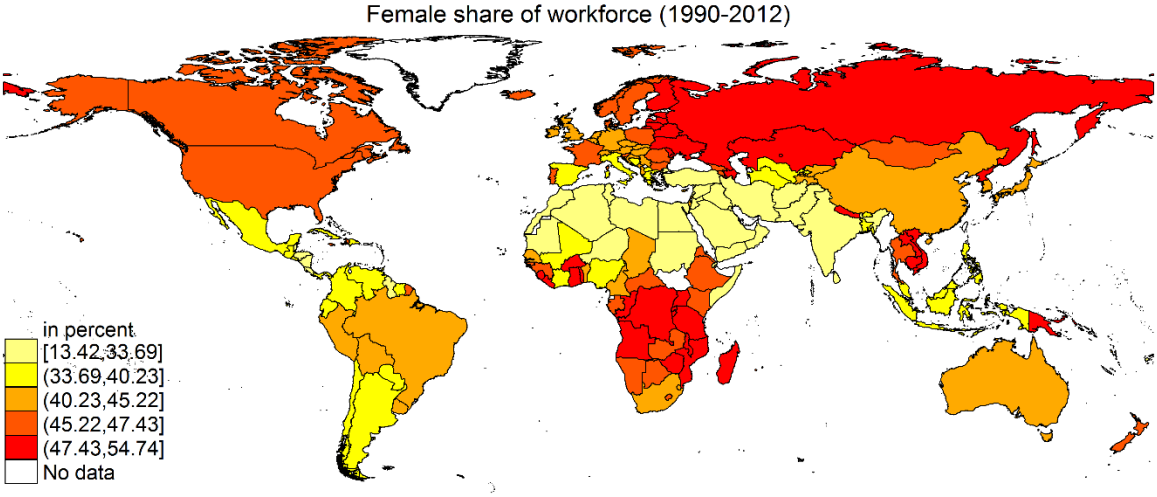
Map A3. Women social rights (averaged over 1981-2007).



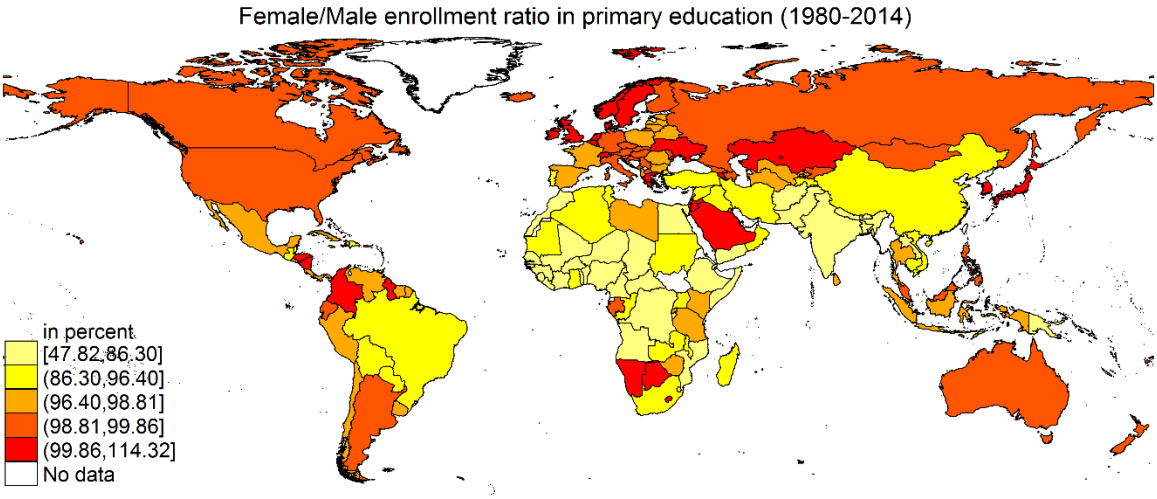
Map A4. Share of women in parliament (average 1990-2014).



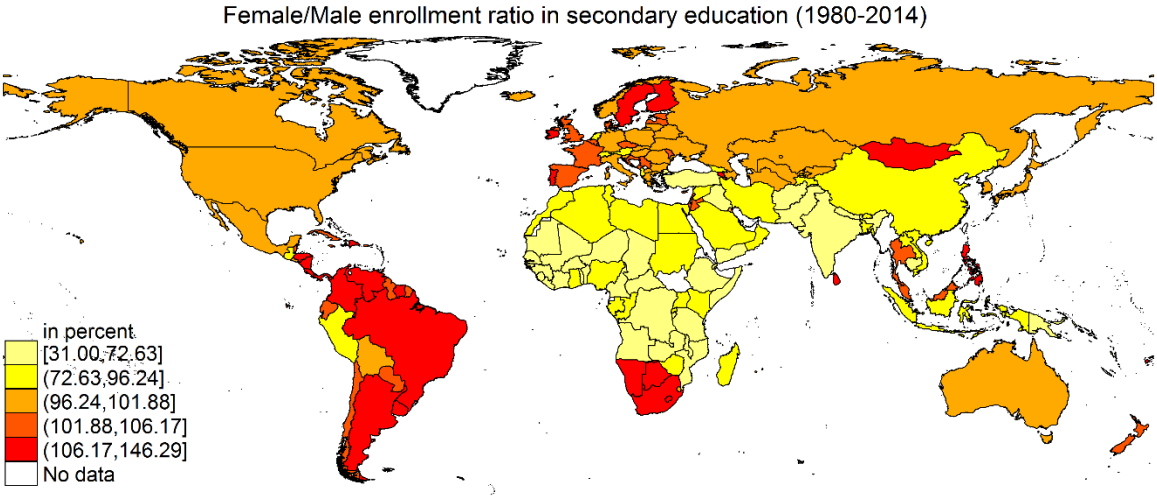
Map A5. Share of women in the workforce (average 1990-2012).



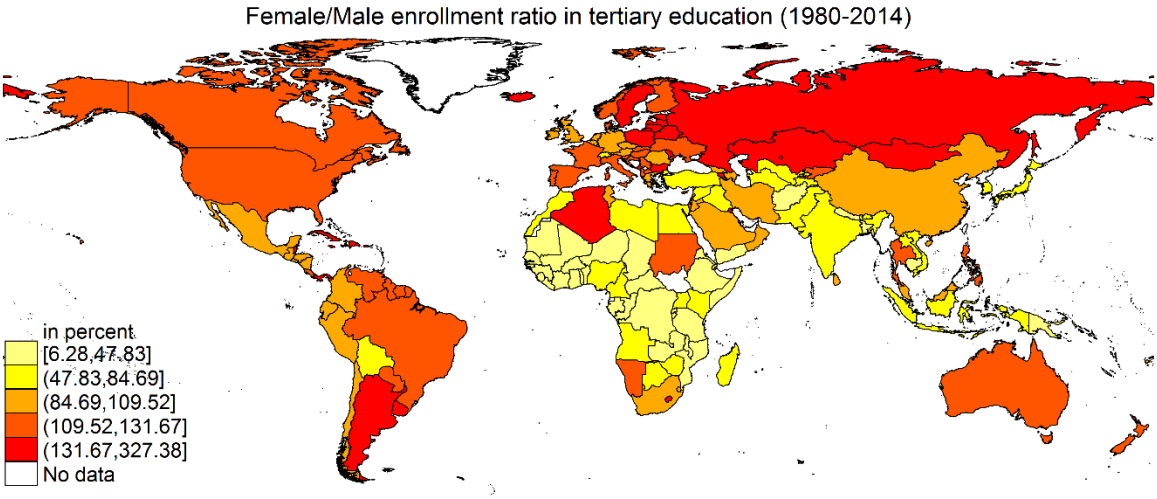
Map A6. Female to male enrolment ratio in primary education (average 1980-2014).



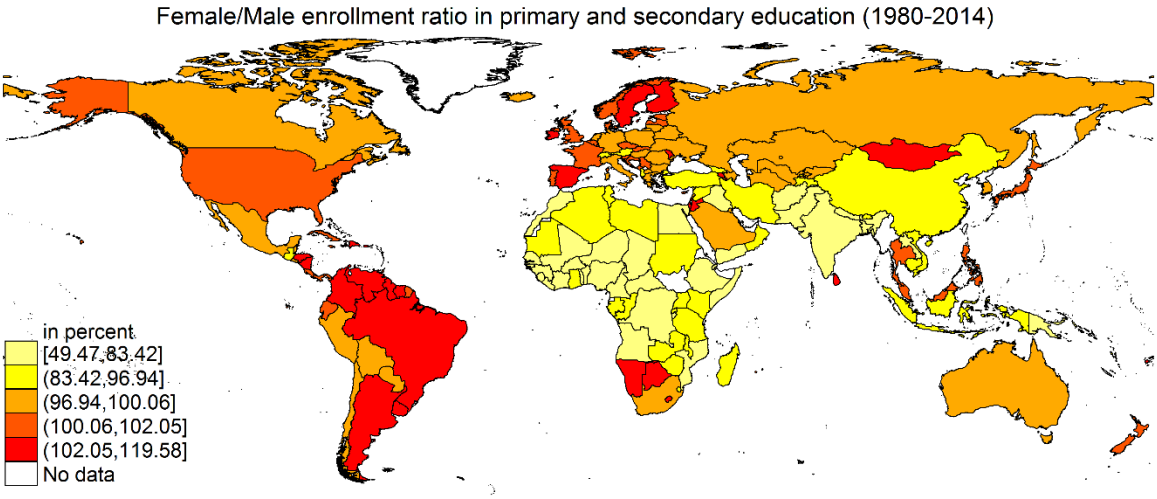
Map A7. Female to male enrolment ratio in secondary education (average 1980-2014).



Map A8. Female to male enrolment ratio in tertiary education (average 1980-2014).



Map A9. Female to male enrolment ratio in primary and secondary education (average 1980-2014).



List of abbreviations

CC	climate change
CIRI	Cingranelli Richards (short form for "The CIRI Human Rights Dataset")
CPI	Corruption Perception Index
CRED	Centre for Research on the Epidemiology of Disasters
e.g.	for example (short for 'exempli grata')
et al.	and others (short for 'et alia')
i.e.	that is (short for 'id est')
IPCC	Intergovernmental Panel on Climate Change
GDP	gross domestic product
OECD	Organisation for Economic Co-operation and Development
PPP	purchasing power parity
QoG	Quality of government dataset
SIDS	Small islands developing states
SWIID	Standardized world income inequality dataset
USSD	United States States Department
U.S.	United States
WDI	World Bank Development Indicators
ZINB	Zero inflated negative binomial model
ZIP	Zero inflated poisson model

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JRC Mission

As the Commission's in-house science service, the Joint Research Centre's mission is to provide EU policies with independent, evidence-based scientific and technical support throughout the whole policy cycle.

Working in close cooperation with policy Directorates-General, the JRC addresses key societal challenges while stimulating innovation through developing new methods, tools and standards, and sharing its know-how with the Member States, the scientific community and international partners.

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Stimulating innovation
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