VU Research Portal

Civil war, climate change, and development: a scenario study for Sub-Saharan Africa

Devitt, C.; Tol, R.S.J.

published in
Journal of Peace Research
2012

DOI (link to publisher)
10.1177/0022343311427417

document version
Publisher's PDF, also known as Version of record

Link to publication in VU Research Portal

citation for published version (APA)
Devitt, C., & Tol, R. S. J. (2012). Civil war, climate change, and development: a scenario study for Sub-Saharan Africa. *Journal of Peace Research*, *49*(1), 129-145. https://doi.org/10.1177/0022343311427417

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal ?

Take down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

E-mail address:
vuresearchportal.ub@vu.nl

Download date: 23. Aug. 2022

Journal of Peace Research

http://jpr.sagepub.com/

Civil war, climate change, and development: A scenario study for sub-Saharan Africa

Conor Devitt and Richard SJ Tol

Journal of Peace Research 2012 49: 129

DOI: 10.1177/0022343311427417

The online version of this article can be found at:

http://jpr.sagepub.com/content/49/1/129

Published by:

SAGE

http://www.sagepublications.com

On behalf of:

Peace Research Institute Oslo

PRIO

Journal of Peace Research Replication Data

Additional services and information for *Journal of Peace Research* can be found at:

Email Alerts: http://jpr.sagepub.com/cgi/alerts

Subscriptions: http://jpr.sagepub.com/subscriptions

Reprints: http://www.sagepub.com/journalsReprints.nav

Permissions: http://www.sagepub.com/journalsPermissions.nav

>> Version of Record - Jan 31, 2012

What is This?

Downloaded from jpr.sagepub.com at Vrije Universiteit 34820 on May 2, 2013

journal of peace RESEARCH

Journal of Peace Research
49(1) 129–145
© The Author(s) 2012
Reprints and permission:
sagepub.co.uk/journalsPermissions.nav
DOI: 10.1177/0022343311427417
jpr.sagepub.com
SAGE

Civil war, climate change, and development: A scenario study for sub-Saharan Africa

Conor Devitt

Booth School of Business, University of Chicago

Richard SJ Tol

Economic and Social Research Institute, Dublin, Vrije Universiteit, Amsterdam & Trinity College, Dublin

Abstract

This article presents a model of development, civil war and climate change. There are multiple interactions. Economic growth reduces the probability of civil war and the vulnerability to climate change. Climate change increases the probability of civil war. The impacts of climate change, civil war and civil war in the neighbouring countries reduce economic growth. The model has two potential poverty traps – one is climate-change-induced and one is civil-war-induced – and the two poverty traps may reinforce one another. The model is calibrated to sub-Saharan Africa and a double Monte Carlo analysis is conducted in order to account for both parameter uncertainty and stochasticity. Although the IPCC Special Report on Emission Scenarios (SRES) is used as the baseline, thus assuming rapid economic growth in Africa and convergence of African living standards to the rest of the world, the impacts of civil war and climate change (ignored in SRES) are sufficiently strong to keep a number of countries in Africa in deep poverty with a high probability.

Keywords

civil war, climate change, economic development

Introduction

The socio-economic scenarios that underpin future projections of climate change are very peaceful (Nakicenovic & Swart, 2001). This is in sharp contrast to the past, which regularly saw violent conflict between and within states. The absence of (civil) war in future scenarios of climate change is even more surprising when one considers that violent conflict can have a profound impact on development (Butkiewicz & Yanikkaya, 2005), and that one of the more worrying assertions is that climate change could enhance violent conflict (Barnett & Adger, 2007). This article seeks to fill this void by developing a simulation model for the three-way interaction between civil war, climate change and development.

The model has a few, simple components: climate change has a negative impact on the economy, slowing down its growth. Climate change increases the probability of civil war. Civil war has a negative impact on economic growth. In turn, economic growth reduces the vulnerability to the impacts of climate change, and it reduces the probability of an outbreak of violent conflict. Although its components are simple, when put together the model is complex.

As far as we know, this is the first attempt to study the three-way interaction between climate change, civil war, and development. Essentially, we model a race.

Corresponding author:
richard.tol@esri.ie

Downloaded from jpr.sagepub.com at Vrije Universiteit 34820 on May 2, 2013

Economic growth reduces the risk of conflict and the impact of climate change. But climate change and conflict reinforce one another and reduce economic growth. If the first effect is stronger, countries will be rich, peaceful and not much bothered by climate change. If the latter effect is stronger, countries will be poor, torn by conflict and suffer from climate change. Phrased like this, the model is used to investigate whether there is a conflict-and-climate-induced poverty trap – or rather, the size of the trap and which countries are more likely to be caught by it.

We qualitatively sketch the mechanisms above. It is therefore possible to construct a mathematical model from which a conflict-and-climate poverty trap emerges. We do so below. We parameterize the model with realistic values and conduct a systematic sensitivity analysis on the parameters. This exercise takes the article from the question 'is it possible?' to 'how likely is it?'.

It would be preferable to investigate the strength of the hypothesized conflict-and-climate poverty trap using observations. However, rapid climate change has not happened in the period for which there are good data on conflict and development. We therefore rely on a simulation model.

While there are a number of articles on the relationship between conflict and economic growth and on climate change and growth, there is little quantitative evidence on conflict and climate change – see the next section for a literature review. Therefore, as a secondary contribution, the article also develops and estimates a model of the impact of climate change on civil war.

As a third contribution, we introduce a new richness to the scenarios of development used in climate change analysis. We apply the model to sub-Saharan Africa, the region that is least developed and most subject to (civil) war.

The article proceeds as follows. The next section reviews the literature. After that, we present the model, with additional material in the appendix. This is followed by a discussion of the results. As with any numerical model, the results follow from the assumptions, which are particularly uncertain in this case. We therefore conduct a systematic sensitivity analysis and focus on the qualitative results. The final section concludes.

Previous literature

Climate and conflict

Existing empirical research on the role of climate change in violent conflict is limited and inconclusive. Homer-Dixon (1994) examines a number of case studies, in order to determine if environmental scarcities cause violent conflict. Evidence from these case studies suggests that while conflict has indeed occurred in areas of resource scarcity, key contextual factors have played an important role. For example, he argues that serious civil unrest is unlikely to occur unless the political structure prevents challenger groups from expressing their grievances peacefully, but offers these groups an opportunity for violence against authority. Later research (Buhaug, 2010a,b; Buhaug & Rød, 2006; Burke et al., 2009, 2010; Dixon, 2009; Gleditsch, 1998; Gleditsch et al., 2006; Hauge & Ellingsen, 1998; Henderson, 2000; Henderson & Singer, 2000; Hendrix & Glaser, 2007; Nordås & Gleditsch, 2007; Raleigh, 2010; Raleigh & Urdal, 2007; Theisen, 2008; Urdal, 2005) finds conflicting evidence about whether or not environment and climate factors contribute to violent conflict. There is a consensus, however, that other, non-environmental factors dominate.

See also the other articles in this special issue, three of which are particularly relevant for our contribution. Gartzke (2012) seeks to estimate the effect of the annual global mean temperature on interstate conflict in the last 150 years but, since he fails to account for non-stationarity in the data (Engle & Granger, 1987), his results are not robust. Using panel data with 30 years and 170 countries, Bergholt & Lujala (2012) find that natural disasters negatively affect economic growth, but that this does not in turn influence the onset of civil war. In a similar analysis, Koubi et al. (2012) find that temperature and precipitation do not affect economic growth, but that growth does reduce the probability of armed civil conflict.

Collier & Hoeffler (1998) were the first to suggest an 'economic theory' of civil conflict – rent-seeking by violence – and to test their predictions with data. Later articles have refined the hypotheses and econometrics (Brunnschweiler & Bulte, 2009; Collier, Hoeffler & Rohner, 2009; Collier & Hoeffler, 2005; Elbadawi & Sambanis, 2000; Justino, 2009; Schollaert & van de Gaer, 2009; van der Ploeg & Poelhekke, 2010; Welsch, 2008; Wick, 2008; Wick & Bulte, 2006). While these articles tend to find a link between material deprivation and conflict and between specific resources and conflict, there is no direct link between climate and conflict. Material deprivation has many causes and climate is at best a contributing factor (Acemoglu, Johnson & Robinson, 2001, 2002; Easterly & Levine, 2003; Gallup, Sachs & Mellinger, 1999; Masters & McMillan, 2001). According to this strand of literature, people may fight over resources that are highly valuable and easy to

Downloaded from jpr.sagepub.com at Vrije Universiteit 34820 on May 2, 2013

smuggle (e.g. diamonds) but they tend not to fight over bulky goods such as water and food – climate- and weather-sensitive resources are, therefore, less conflict-prone.

Below, we augment the empirical work of Collier, Hoeffler & Rohner (2009) and find that drought does impact the probability of civil war. This finding is obviously in contrast with some of the literature touched on above. We therefore also show a sensitivity analysis without any impact of climate change on the risk of civil war.

Conflict and growth

From an economic perspective, the consequences of conflict may be severely damaging. Collier (1999) investigates the consequences of civil war for GDP, during the conflict years and in the early years following. He finds that during civil wars GDP per capita declines at an annual rate of 2.2%, relative to its counterfactual. This is partly explained by reduced production but is also the result of a gradual loss of the capital stock. Capital-intensive and transaction-intensive sectors will be severely affected: manufacturing, construction, transport, distribution and finance will all contract more rapidly than GDP. Collier argues that the restoration of peace does not necessarily imply a peace dividend, or a large bounce-back effect, as might be expected. He finds that if a civil war lasts only one year, it causes a loss of growth of 2.1% per annum, in the first five years of peace. This loss of growth is not significantly different from the loss that would have been experienced had the war continued. If the war has been sufficiently long, however, Collier argues that the repatriation of capital enables the economy to grow rapidly. Empirically he finds that after a 15-year war, the post-war growth rate is enhanced by 5.9% per annum. Later articles find similar effects, and also study the spillover effects on neighbouring countries and trading partners (Asteriou & Price, 2001; Azam, Fosu & Ndung'u, 2002; Bayer & Rupert, 2004; Bozzoli, Brück & Sottsas, 2010; Butkiewicz & Yanikkaya, 2005; Carmignani, 2003; De Groot, 2010; Fosu, 2003; Gyimah-Brempong & Corley, 2005; Kang & Meernik, 2005; Koubi, 2005; Murdoch & Sandler, 2002).

Climate and growth

Climate change would affect economic growth and development, but our understanding is limited. Fankhauser & Tol (2005) investigate four standard models of economic growth and three transmission mechanisms: economic production, capital depreciation and the labour force. They find that, in three models, the fall in economic output is slightly larger than the direct impact on markets – that is, the total impact is more than twice as large as the direct impact – while the 4th model (which emphasizes human capital accumulation) points to indirect impacts that are 1.5 times as large as the direct impacts. The difference is explained as follows. In the three models, impacts crowd out consumption and investment in physical capital, while in the fourth model investment in human capital too is crowded out. Hallegatte (2005) reaches a similar conclusion. Hallegatte & Théry (2007) highlight that the impact of climate change through natural hazards on economic growth can be amplified by market imperfections and the business cycle. Eboli, Parrado & Roson (2010) use a multi-sector, multi-region growth model. The impact of climate change would lead to a 0.3% reduction of GDP in 2050. Regional impacts are more pronounced, ranging from –1.0% in developing countries to +0.4% in Australia and Canada.

Using a biophysical model of the human body's ability to do work, Kjellstrom et al. (2009) find that by the end of the century, climate change may reduce labour productivity by 11–27% in the humid (sub)-tropics. Assuming an output elasticity of labour of 0.8, this would reduce economic output in the affected sectors (involving heavy manual labour without air conditioning) by 8–22%. Although structural change in the economy may well reduce the dependence on manual labour and air conditioning would be an effective adaptation, even the ameliorated impact would have a substantial, but as yet unquantified, impact on economic growth.

In a statistical analysis, Dell, Jones & Olken (2009) find that one degree of warming would reduce income by 1.2% in the short run, and by 0.5% in the long run. The difference is due to adaptation. Horowitz (2009) finds a much larger effect: a 3.8% drop in income in the long run for one degree of warming. In a yet-unpublished study, Dell, Jones & Olken (2008) find that climate (change) has no effect on economic growth in countries with an income above the global median (USD ^{PPP,2000}3,170) but a large impact on countries below the median. If companies can fully adapt to a new climate in 10 years time, economic growth in the 21st century would be 0.6% slower if climate changes according to the A2 scenario than in the case without climate change. This is a large impact. For example, if economic growth is 2.6% per year without climate change, and 2.0% with, then a century of climate change would reduce income by 44%.

Downloaded from jpr.sagepub.com at Vrije Universiteit 34820 on May 2, 2013

The above studies are about the impact of climate and climate change on economic growth. However, some countries (or groups of people within countries) have not enjoyed any growth at all, living at subsistence level much like previous generations did.

Poverty is concentrated in the tropics and subtropics. This has led some analysts to the conclusion that a tropical climate is one of the causes of poverty. Gallup, Sachs & Mellinger (1999) emphasize the link between climate, disease and poverty, while Masters & McMillan (2001) focus on climate, agricultural pests and poverty. Other studies (Acemoglu, Johnson & Robinson, 2001, 2002; Easterly & Levine, 2003) argue that climatic influence on development disappears if differences in human institutions (the rule of law, education, etc.) are accounted for. However, van der Vliert (2008) demonstrates that climate affects human culture and thus institutions, but this venue has yet to be explored in the economic growth literature. Bloom, Canning & Sevilla (2003) find limited support for an impact of climate change on past growth in a single-equilibrium model, but strong support in a multiple-equilibrium model: hot and wet conditions and large variability in rainfall reduce long-term growth in poor countries (but not in hot ones) and increase the probability of being poor.

There are two equilibria in the model of Galor & Weil (1996). One is characterized by high population growth and low capital intensity (the 'Malthusian' equilibrium), the other by low population growth and high capital intensity (the 'Solowian' equilibrium). Physical labour plays a more important role in setting wages, output and savings in the Malthusian equilibrium than in the Solowian equilibrium. This implies that anything that affects physical labour is more important in the Malthusian equilibrium than in the Solowian one. And, as capital intensity separates the two equilibria, reduced productivity of physical labour would reduce savings and capital intensity and hence lock the economy deeper into the poverty trap. Physical labour would be negatively affected by an increase in morbidity and by a decrease of crop yields (as the model implicitly assumes that physical labour is primarily used in agriculture). Skilled labour is affected by long-term cognitive impairment, which is associated with childhood malnutrition and disease, both of which are linked to climate. Climate may thus help to explain the occurrence of poverty traps, and climate change could widen poverty traps.

Bonds et al. (2010) and Strulik (2008) posit theoretical models and offer limited empirical support. Climate-related diseases such as malaria and diarrhoea impair children's cognitive and physical development. This leads to poverty in their later life so that there are limited means to protect their own children against these diseases. Furthermore, high infant mortality may induce parents to have many children so that their investment in education and health care is spread thinly. An increase in infant and child mortality and morbidity due to climate change would thus trap more people in poverty.

In sum, the literature on the impact of climate and climate change on economic growth and development has yet to reach firm conclusions. There is agreement that climate change would moderate the rate of economic growth, by a little according to some studies and by a lot according to other studies. There is disagreement whether climate change would affect the nature of economic development, with some studies suggesting that more people may be trapped in poverty and fewer people might enjoy exponential growth. The latter effect is potentially more important – contrast the difference between 0% and 1% growth, and between 1% and 2% growth – but beyond the scope of the current article.

The model

Overview

The structure of the model, depicted in Figure 1, is as follows. There are six equations and six variables (see Table I). The risk of civil war is higher if people are poorer, if economic growth is slower, and if more people are affected by drought (Equation 1). The risk of drought is higher if people are poorer and there is less precipitation (Equation 2). Precipitation changes with climate (Equation 3). The number of people affected by drought, assuming there is one, falls as people grow richer (Equation 4). The impact of climate change gets worse as climate change gets more severe and as people are poorer (Equation 5). Economic growth is slower if a there is civil war in the country or in a neighbouring country, and if the impact of climate change is more negative (Equation 6). These equations make intuitive sense – the specifications and parameters are discussed below. Parameters are listed in Table II.

The qualitative behaviour of the model is as follows. Climate change drives its economic impact and affects the risk of civil war. Economic growth affects the impact of climate change and is affected by it. Economic growth affects the risk of civil war and is affected by it. This means that there are two potential poverty traps in the model – sluggish growth leading to civil war and further slow growth; climate change slowing growth and enhancing vulnerability to climate change – and the two poverty traps may reinforce one another.

Downloaded from jpr.sagepub.com at Vrije Universiteit 34820 on May 2, 2013

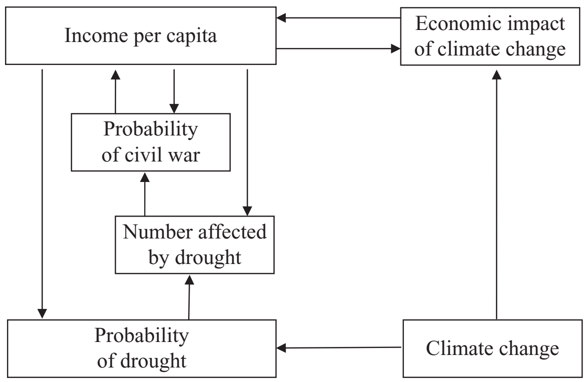

Figure 1. Flow diagram of the model

Equations

The risk of civil war is based on Collier, Hoeffler & Rohner (2009); see Appendix 1 for more detail, particularly on adding drought as a driver of civil war. We experimented with a number of climate variables in the context of the Collier model. Whereas a range of temperature and precipitation variables are not significant, the number of people affected by drought is. The risk of civil war is specified as a logistic function. It is given by

$$W_{c,t} = \frac{1}{1+e^{-Z_{c,t}}} \text{ with } Z_{c,t} := \alpha_0 + \alpha_{1,c} + \alpha_2 \ln y_{c,t} + \alpha_3 \frac{y_{c,t} - y_{c,t-1}}{y_{c,t-1}} + \alpha_4 A_{c,t} \quad (1)$$

where

- $W_{c,t}$ is the risk of civil war in country c at time t;
- c indexes countries;
- t indexes time;
- $y_{c,t}$ is per capita income in country c at time t;
- $A_{c,t}$ is the number of people (per million inhabitants) affected by drought in country c at time t; these parameters are estimated; see Appendix 1;
- $\alpha_2 = -0.33$ (0.12), $\alpha_3 = -0.061$ (0.030) and $\alpha_4 = 0.0073$ (0.0040) are parameters;
- $\alpha_{1,c}$ is a country specific constant[1]; see Appendix 2; and
- α_0 is a calibration constant such that the probability of a civil war is 6% in 2005 (when 3 out of 50 sub-Saharan African countries were at civil war); we calibrate to 2005 because that is the starting point of the simulations; note that civil war was at a historical low in 2005: on average over the period 1960–2000, 19% of African countries were in a civil war; calibration is necessary in the Monte Carlo analysis over the other parameters in Equation (1).

The risk of being affected by drought is determined by both annual precipitation (the risk of drought) and per capita income (the risk of suffering adverse impacts). It is given by

$$D_{c,t} = \frac{1}{1+e^{-Z_{c,t}}} \text{ with } Z_{c,t} := \beta_0 + \beta_1 \ln y_{c,t} + \beta_2 P_{c,t} \quad (2)$$

where

- $D_{c,t}$ is the risk of drought in country c at time t;
- $P_{c,t}$ is precipitation in country c at time t; see Appendix 2; and
- $\beta_0 = 4.0$ (0.4), $\beta_1 = -0.75$ (0.06) and $\beta_2 = -0.00025$ (0.00010) are parameters; these parameters are estimated; see Appendix 1.

Projections of precipitation are not particularly reliable. We therefore choose the simplest specification. Precipitation follows

$$P_{c,t} = \eta_{c,0} + \eta_{c,1} T_t \quad (3)$$

where

- T_t is the global mean surface air temperature (in degrees Celsius above pre-industrial); and
- $\eta_{c,0}$ and $\eta_{c,1}$ are country-specific parameters taken from Christensen et al. (2007); see Appendix 2 in the replication file.

Similarly, the specification of the number of people affected by drought is kept simple. No new variables (and hence no new scenario uncertainties) are introduced. The equation is monotonous. It is given by

$$A_{c,t} = \begin{cases} \gamma_0 + \gamma_1 \ln y_{c,t} & D*_{c,t} = 1 \\ 0 & D*_{c,t} = 0 \end{cases} \quad (4)$$

where

- $D^*_{c,t}$ is drought in country c at time t; and
- $\gamma_0 = 34$ (16), and $\gamma_1 = -4.1$ (2.4) are parameters; these parameters are estimated; see Appendix 1.

For the impact of climate change, we used the simplest functional form that can emulate the characteristics of *FUND*, an integrated assessment model with a

[1] The econometric model as estimated by Collier, Hoeffler & Rohner (2009) and re-estimated by ourselves contains a number of other control variables, which are held constant during the simulations.

Downloaded from jpr.sagepub.com at Vrije Universiteit 34820 on May 2, 2013

Table I. Model variables

Symbol	*Description*	*Unit*	*Equation*
$W^{(*)}$	(Risk of) civil war	Number of conflicts per year	1
$D^{(*)}$	(Risk of) drought	Dummy variable	2
P	Precipitation	Millimetres per year	3
A	Number affected by drought	People per thousand inhabitants	4
C	Impact of climate change	Percent of gross domestic product	5
Y	Per capita income	Dollar per person per year	6

Table II. Model parameters

Symbol	*Description*	*Value*	*Source*
α_0	Basic risk of civil war	Calibrated	
α_1	Effect of log income on civil war	−0.33 (0.12)	App A
α_2	Effect of income growth on civil war	−0.061 (0.030)	App A
α_3	Effect of drought on civil war	0.0073 (0.0040)	App A
β_0	Basic risk of drought	4.0 (0.4)	App A
β_1	Effect of log income on drought	−0.75 (0.06)	App A
β_2	Effect of precipitation on drought	0.00025 (0.00010)	App A
$\eta_{c,0}$	Precipitation in 2005	Table B.I	App B
$\eta_{c,1}$	Effect of climate change on precipitation	Table B.I	App B
γ_0	Constant number of people affected by drought	34.2 (15.6)	App A
γ_1	Effect of log income on number of people affected by drought	−4.05 (2.42)	App A
λ_c	Basic impact of climate change	Table B.I	App B
λ_1	Effect of income on impact of climate change	$1.0\ 10^{-4}$ $(0.1\ 10^{-4})$	App C
λ_2	Effect of temperature squared on impact of climate change	−0.48 (0.01)	App C
$\kappa_{c,t}$	Basic income growth rate	Table B.I	App B
κ_1	Effect of own civil wars on economic growth	0.022 (0.011)	Collier
κ_2	Effect of neighbours' civil wars on economic growth	0.009 (0.004)	Collier
κ_3	Effect of climate change impact on economic growth	0.05 (0.02)	Collier

particularly rich representation of the impacts of climate change (Link & Tol, 2011; Tol, 2002a,b). Impacts and marginal impacts increase in temperature but (relative to economic activity) decrease in economic growth. It is given by

$$C_{c,t} = \lambda_{c,0} + \lambda_1 \ln y_{c,t} + \lambda_2 T_t^2 \quad (5)$$

where

- $C_{c,t}$ is the impact of climate (in % of GDP) in country c at time t;
- T_t is the global mean surface air temperature (in degrees Celsius above pre-industrial); and
- $\lambda_1 = 0.00010$ (0.00001); and $\lambda_2 = -0.48$ (0.01) are parameters; $\lambda_{c,0}$ is a country-specific constant; see Appendix 2; these parameters estimated as a statistical surface of the *FUND* 2.8n model; see Appendix 3.

As above, we use a simple specification of economic growth. There is an exogenous growth path, perturbed by civil war in the own country, civil war in neighbouring countries, and climate change. Growth is given by

$$y_{c,t} = (1 + g_{c,t}) y_{c,t-1} \quad (6a)$$

$$g_{c,t} = \kappa_{c,t,0} + \kappa_1 W*_{c,t-1} + \kappa_2 \sum_{j \neq c} W*_{j,t-1} I_{c,j} + \kappa_3 C_{c,t-1} \quad (6b)$$

where

- $g_{c,t}$ is the growth rate of country c at time t;
- $W^*_{c,t}$ denotes civil war in country c at time t;
- I is an indicator function, 1 if countries c and j share a border, and 0 otherwise;
- $C_{c,t}$ denotes the impact of climate change in country c at time t;
- $\kappa_1 = -0.022$ (0.011); $\kappa_2 = -0.009$ (0.004) and $\kappa_3 = -0.05$ (0.02) are parameters; these parameters are calibrated; $\kappa_{c,t,0}$ is a country- and period-specific

Downloaded from jpr.sagepub.com at Vrije Universiteit 34820 on May 2, 2013

constant, capturing all variables omitted from Equation (6b); see Appendix 2.

Scenarios

The baseline economic growth rate κ_0 is taken from the IMAGE2.2 implementation of the IPCC SRES scenarios (IMAGE Team, 2001). IMAGE2.2 distinguished between three regions (east, south, west) in sub-Saharan Africa. We assume that every country within a region grows at the same rate. The SRES scenarios (Nakicenovic & Swart, 2001) ignore the impact of climate change on development[2] – so that indeed we should calibrate κ_0 rather than g to SRES.

We use the four SRES baseline scenarios. The A1 scenario assumes low population growth, rapid economic growth and rapid technological progress. A2 assumes high population growth, slow economic growth and slow technological progress. B1 assumes low population, rapid economic growth and very rapid technological progress, particularly in energy supply and use. B2 assumes moderate population growth, moderate economic growth and moderate technological progress.

Even the 'slow' economic growth assumed in the A2 scenario is, in fact, fairly rapid in its historical context. The IPCC is a UN body, and Africa has a large block of votes.[3] The SRES models rely on Solow's (1956) growth theory to predict unconditional convergence of income, a theory now widely seen as unsuitable (Barro & Sala-i-Martin, 1995) especially for Africa (Easterly, 2002). Unfortunately, there are no alternative scenarios available and building integrated scenarios of population growth, economic development and energy use is a rather complicated and elaborate activity.

Simulations

We conduct a double Monte Carlo analysis. In the outer loop, we consider parameter uncertainty. We use a Latin Hypercube sample of size 60 for all parameters (cf. Section 3.2). In the inner loop, we consider stochasticity, particularly the outbreak of civil war and drought. We use a simple sampling scheme with 2,000 runs. This makes a total of 120,000 runs.

The Monte Carlo analysis in the outer loop is best interpreted as a systematic sensitivity analysis around the best guess for the model parameters. Although we present numerical results below, the reader should focus on the qualitative results.

Results

The model has six variables: temperature (as an indicator of climate change), the probability of drought, the number of people affected by drought, the economic impact of climate change, the probability of civil war, and per capita income. We are primarily interested in the latter three variables, and particularly the evolution of per capita income and the possibility of a climate-change-induced poverty trap. Nevertheless, the first three variables are needed to understand the behaviour of the model and the results. We therefore briefly discuss these before turning to the main findings. Figure 1 shows that, apart from climate change, everything depends on everything else. We therefore first present the results at a phenomenological level (the model says ...) before turning to the interpretation and meaning of the results.

There are many countries in the model, many runs in the Monte Carlo analysis of parameter uncertainty, and many runs in the Monte Carlo analysis of war and drought stochasticity. That is, there are a lot of results. We present and interpret the results mainly for the expected values for three countries – the Democratic Republic of the Congo (Kinshasa), Lesotho and Gabon – which are the countries with the lowest, median and highest expected per capita income in 2100.

Figure 2 shows the global mean temperature over the 21st century. It is assumed to rise from 0.8°C to 3.1–3.7°C above the pre-industrial (1750) level over the course of the century. The atmospheric concentration of carbon dioxide is highest in the A2 scenario but so are sulphur emissions (which cause regional cooling); the A1 scenario therefore shows the highest temperature. The B1 scenario shows the least warming. Precipitation is assumed to be a linear function of temperature – see Equation (3) – and thus shows the same pattern as temperature.

Figure 3 shows the number of people affected by drought over the 21st century for the A1 scenario. As 'drought' is defined as drought that does reportable damage – see Equation (2) – it depends also on per capita income – see Figure 1 – and is therefore an uncertain and stochastic variable. The number of people affected further depends on per capita income – see Equation (2). Figure 3 therefore displays the expected

[2] IPCC assessments progress unidirectionally from greenhouse gas emissions via climate change to the impacts of climate change. This reflects the state-of-the-art at the time of the foundation of the IPCC, in 1988.

[3] This article is not the right place to discuss the IPCC. See Tol (2011) and references therein.

Downloaded from jpr.sagepub.com at Vrije Universiteit 34820 on May 2, 2013

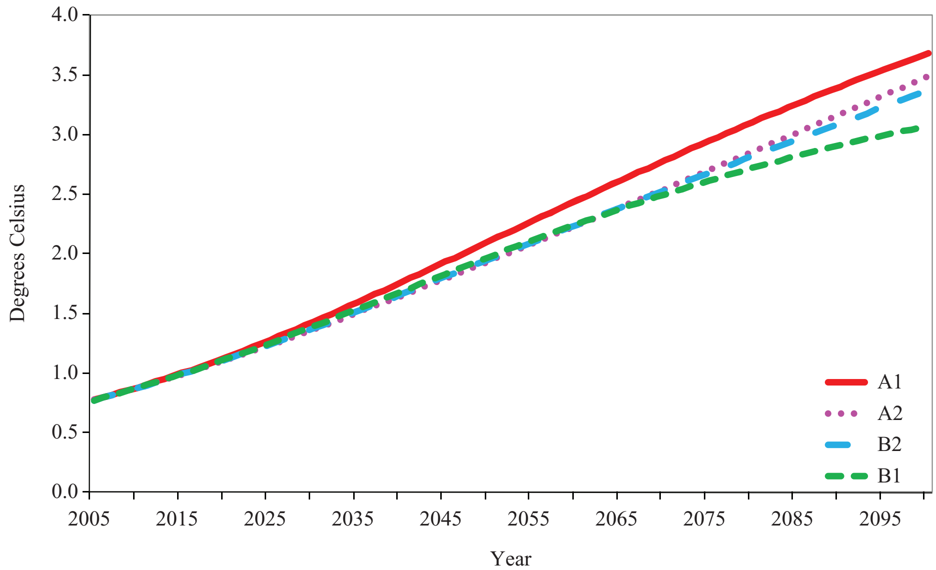

Figure 2. The global mean temperature for the four scenarios

value of the number of people affected by drought. For Lesotho, about five people in 1,000 suffer from drought in 2005. This falls by a factor eight over the course of the century. For Gabon, the drop is much steeper – a factor 33 – and from a lower base at that: one person in a thousand. The reverse is observed for the DR Congo. Some 12 people in a thousand are affected by drought in 2005; this falls at first, but then starts rising again in the second half of the century to about ten people in a million in 2100. There is a strong divergence between the countries of sub-Saharan Africa with regard to the seriousness of drought – which suggests that some countries may be caught in a poverty trap while others grow exponentially.

Figure 3 also shows results for the median country (Lesotho) under the four alternative scenarios. Results are very similar for A1 and B1, but the incidence of drought is considerably higher under B2 and particularly A2. These differences are primarily due to the assumed growth rate of per capita income; the change in precipitation has little impact.

Figure 4 shows the expected impact of climate change over the 21st century. Impacts are expressed as the welfare-equivalent income loss. For instance, in Lesotho, climate change reduces the welfare equivalent to losing over 4% of income in 2010. This rises to over 8% in 2100. For the DR Congo, the impact in 2100 would be almost 13% of GDP. The pattern for Gabon is different. A loss of 3% at the start of the century is turned into a gain of the same size by the end of the century as development has removed the main vulnerabilities to climate change and opened new opportunities to take advantage of climate change (e.g. through carbon dioxide fertilization of crops). As with drought, there is a strong divergence between countries – hinting at the existence of the poverty trap for some but not all countries.

Figure 4 also shows results for Lesotho under the four alternative scenarios. Impacts are less severe under B1 than under A1, primarily because climate change is less pronounced under B1 (cf. Figure 2). Impacts are more severe under B2 and worse still under A2. These differences are largely because of differences in per capita income.

Figure 5 shows the expected probability of civil war over the 21st century. For Lesotho, the probability of civil war starts at 2%, increases to over 5% and then tapers off to 3% as climate change and underdevelopment are the dominant signals in the medium term but development is the dominant signal in the long term. For Gabon, the expected probability of civil war starts at a low 0.4% and falls to almost zero. For the DR Congo, the expected probability of civil war starts high (69%) and remains high (62%). The combined impact of civil war and climate change mean that development in the DR Congo stagnates – and the country remains prone to civil war as a result. As with drought and climate change impacts, there is a strong divergence between countries – another sign of some countries trapped in poverty and other countries escaping.

Figure 5 also shows results for Lesotho under the four alternative scenarios. Results are almost identical for the A1 and B1 scenarios. However, the risk of civil war is

Downloaded from jpr.sagepub.com at Vrije Universiteit 34820 on May 2, 2013

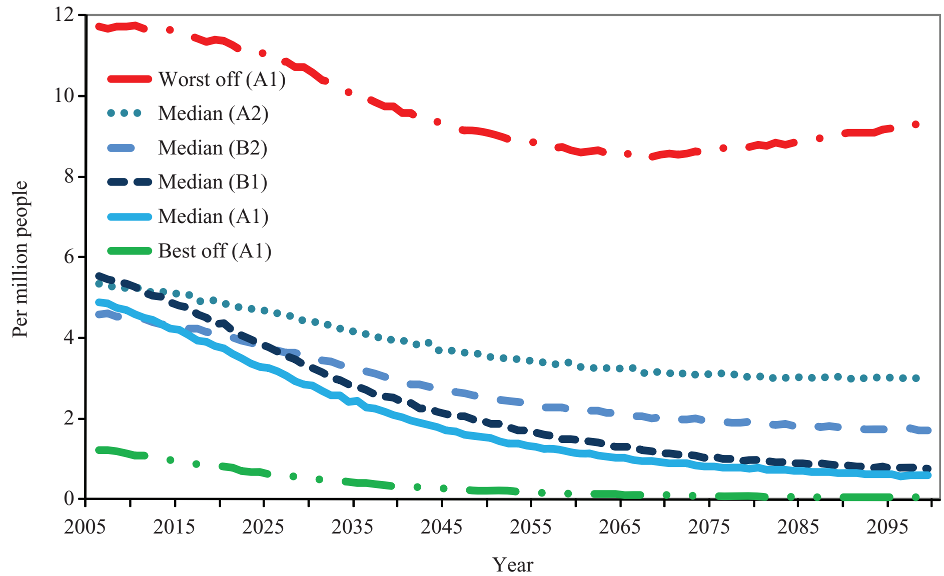

Figure 3. The expected fraction of people affected by drought for the best off (Gabon), worst off (DR Congo) and median (Lesotho) country in 2100

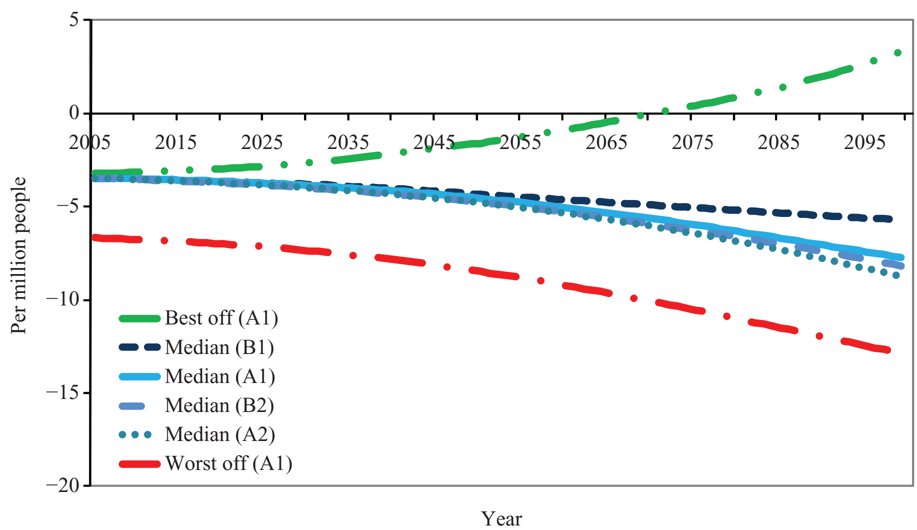

Figure 4. The expected impact of climate change for the best off (Gabon), worst off (DR Congo) and median (Lesotho) country in 2100

higher under the B2 scenario and higher still under the A2 scenario. These differences and similarities primarily reflect differences in the assumed economic growth rate; climate change has a minor impact.

Figure 6 shows the expected income per capita over the 21st century. For Lesotho, income rises from some USD 500 per person per year at the start of the century to almost USD 13,000/p/y at the end – a 26-fold increase. For the DR Congo, income rises too but only 7-fold from less than USD 100/p/y to less than USD 700/p/y. For Gabon, income rises 90-fold from USD 4,000/p/y to USD 350,000/p/y. A 90-fold increase over a century corresponds to an annual growth rate of 4.5%, well within the range of historical experience. As with the previous three indicators, there is divergence, big time. Evaluated at the mean, the DR Congo is not quite caught in a poverty trap, but economic growth is very slow. The

Downloaded from jpr.sagepub.com at Vrije Universiteit 34820 on May 2, 2013

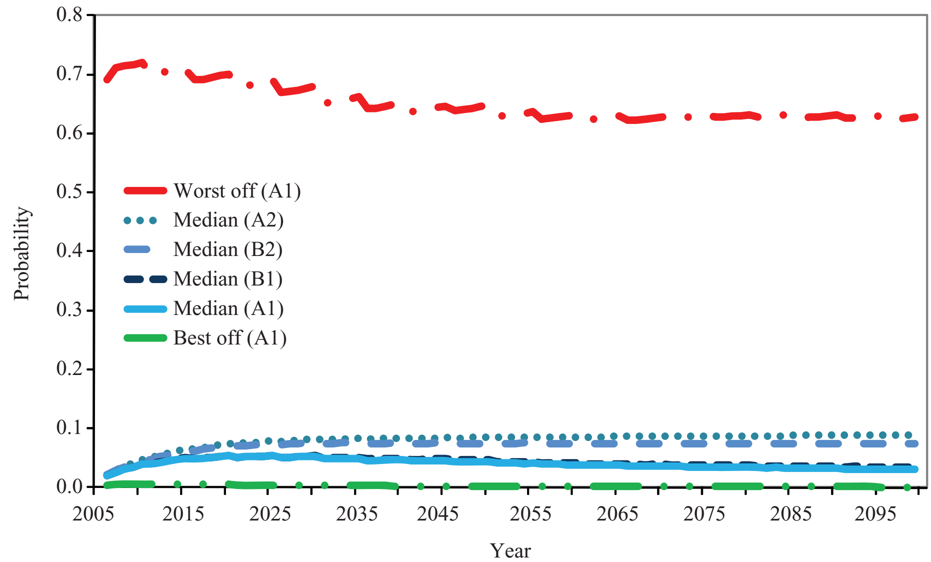

Figure 5. The expected probability of civil war for the best off (Gabon), worst off (DR Congo) and median country (Lesotho) in 2100

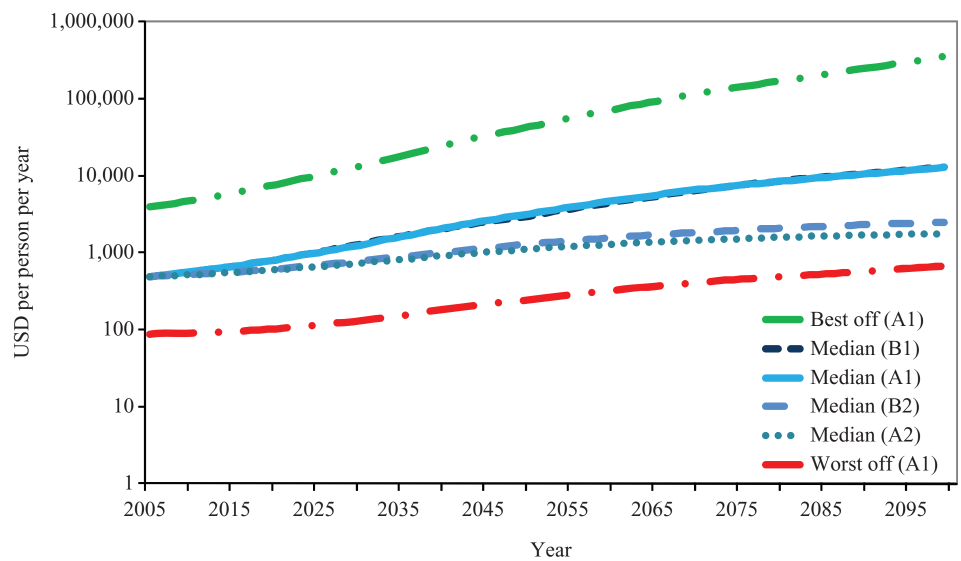

Figure 6. The expected per capita income for the best off (Gabon), worst off (DR Congo) and median country (Lesotho) in 2100

economies of other two countries display more healthy levels of growth.

Figure 6 also shows results for Lesotho for the four alternative scenarios. Per capita income is roughly the same under A1 and B1. However, it is much lower under B2 and lower still under A2. This partly reflects the assumptions, but the differences are enhanced by the impacts of civil war and climate change on economic growth.

Figure 7 shows the expected income per capita in 2100 for Lesotho (1) for the complete model, (2) for the model with the risk of civil war set to zero, (3) for the model with the impact of climate change set to zero, (4) for the model with climate change set to zero, and (5) for the model with both climate change and civil war risk set to zero. Model 5 corresponds to the IPCC scenario. In Model 1, climate change affects growth through two channels: economic impact and civil war; in Models 2 and 3 only one of these channels is operative; in Model 4, there is no impact of climate change. In Model 4, civil war affects growth, and in Model 1 this is enhanced by climate change.

Downloaded from jpr.sagepub.com at Vrije Universiteit 34820 on May 2, 2013

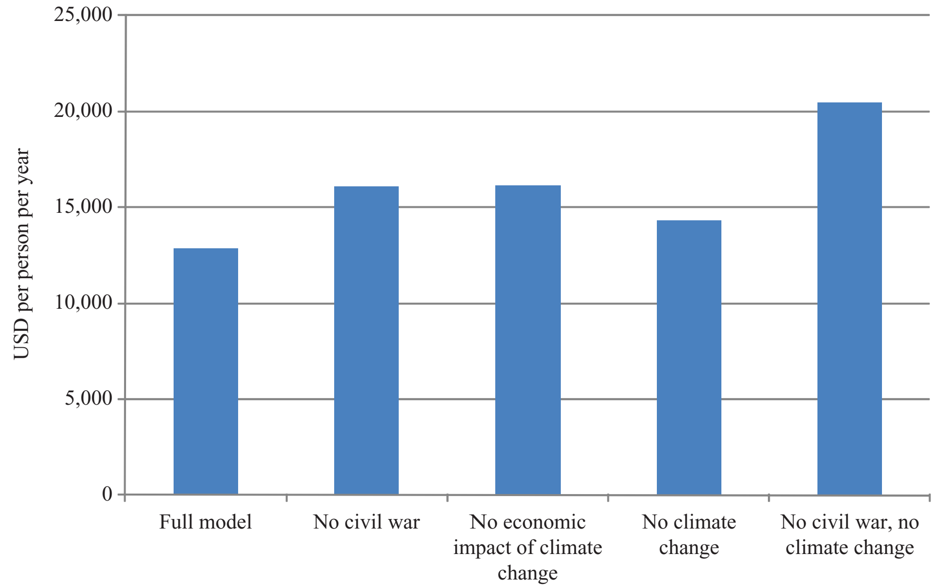

Figure 7. The expected per capita income for the median country (Lesotho) in 2100 for the full model and models without one or both risk factors

Civil war and the economic impact of climate change have a similar effect (but note that the two interact): without civil war, Lesotho would expect to be USD 3,200/p/y richer in 2100; without the economic impacts of climate change, per capita income would be USD 3,300 higher. Without climate change and civil war, income would be USD 7,600 higher. There is therefore a negative synergy (of USD 1,100/p/y) between the economic impacts of climate change and civil war. Without climate change (but with the baseline risk of civil war), income would be USD 1500 higher. Climate change thus more than doubles (from USD 1,500 to USD 3,300) the negative economic impacts of civil war. Taken separately, climate change and civil war have a relatively modest impact on economic growth. Taken together, the impact is more substantial – and indeed the sum is greater than the parts. A conflict-and-climate poverty trap is therefore more likely than either a climate poverty or a conflict poverty trap.

Figure 8 shows the expected impact of climate change in 2100 for Lesotho for the complete model, and for the model with the risk of civil war set to zero. The effect of civil war is small, raising the impact from 7.4% to 7.7% of GDP. Figure 9 shows the expected probability of civil war over the 21st century for the complete model, for the model without the impact of climate change on civil war, and for the model with the impact of climate change set to zero. The direct impact of climate change is modest (which follows from the regression results and indeed the literature review) and mixed (which follows from the opposite effects of climate change and development); climate change accentuates the pattern seen in Figure 5. The economic impacts of climate change, through their effect on economic growth, increase the probability of civil war by 1% in 2100. While absolute small, this is relatively large as the probability of civil war is 4% without the economic impacts of climate and 5% with. Together, Figures 8 and 9 confirm the synergistic nature of climate change and civil war.

Figure 10 shows the probability density function of per capita income in the year 2100. The distribution for Lesotho shows clear bimodality, as indeed suggested by the qualitative discussion of the model properties. The primary mode is an income of around USD 14,000 per person per year; the secondary mode is around USD 9,000/p/y. Less than 10 (out of 120,000) realizations are greater than USD 18,000/p/y, while the model without climate change and civil war would lift the average income in 2100 to USD 20,000/p/y. The impact of climate change and civil war on economic growth is unambiguously negative – and the bimodality is clear evidence that, if economic growth is insufficiently fast, climate change and civil war may hold back growth further.

The probability distribution for Gabon is unimodal, with a single peak around USD 356,000/p/y. This is lower than the scenario without climate change and civil war (USD 425,000/p/y). Interestingly, although the economic

Downloaded from jpr.sagepub.com at Vrije Universiteit 34820 on May 2, 2013

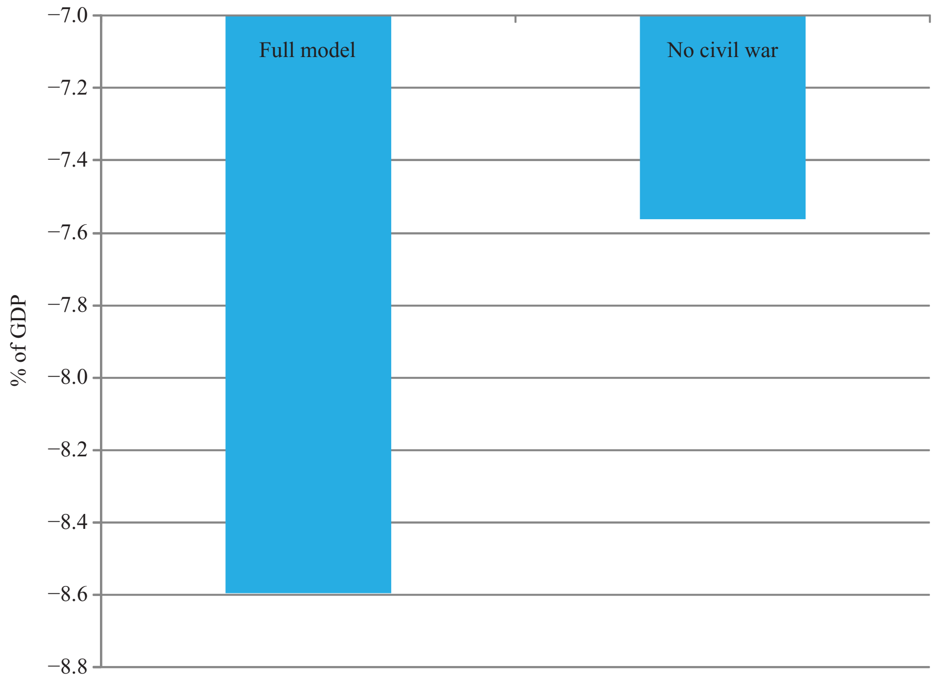

Figure 8. The expected impact of climate change for the median country (Lesotho) in 2100 with and without the risk of civil war

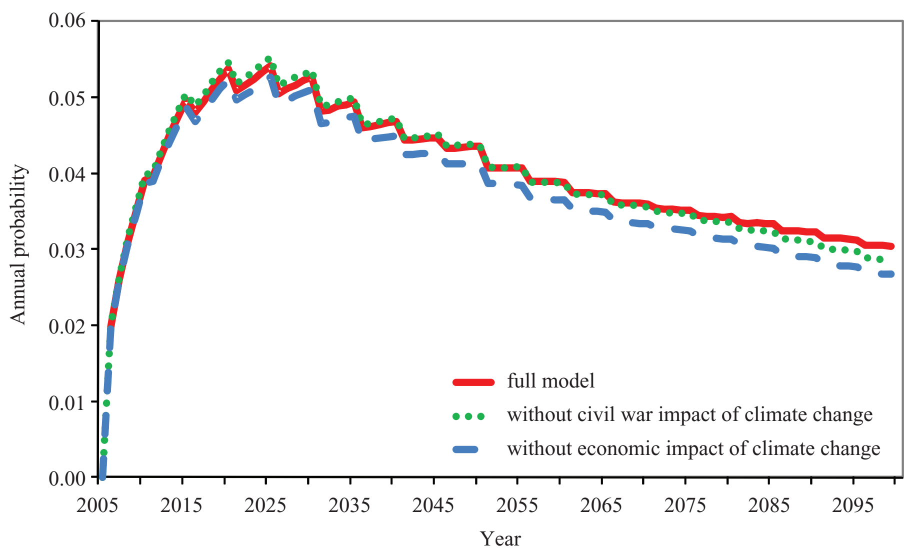

Figure 9. The expected probability of civil war for the median country (Lesotho) in 2100 with and without economic impacts of climate change and the impact of climate change on civil war

impact of climate change is expected to be positive for Gabon (cf. Figure 4), only 33 (out of 120,000) realizations see a net acceleration of economic growth over the century. This is because the negative impacts on growth in the early years are more important than the positive effects in later years. The left tail of the distribution shows that the negative economic impacts of climate change and civil war may be substantial – in the worst case, income in 2100 is 46% of the modal income – but the unimodality suggest that this would not lead to a poverty trap – indeed, in the worst case, per capita income grows by 3.8% per year.

The DR Congo's probability distribution is unimodal too, with a single peak at subsistence level. Without climate change and civil war, the DR Congo's

Downloaded from jpr.sagepub.com at Vrije Universiteit 34820 on May 2, 2013

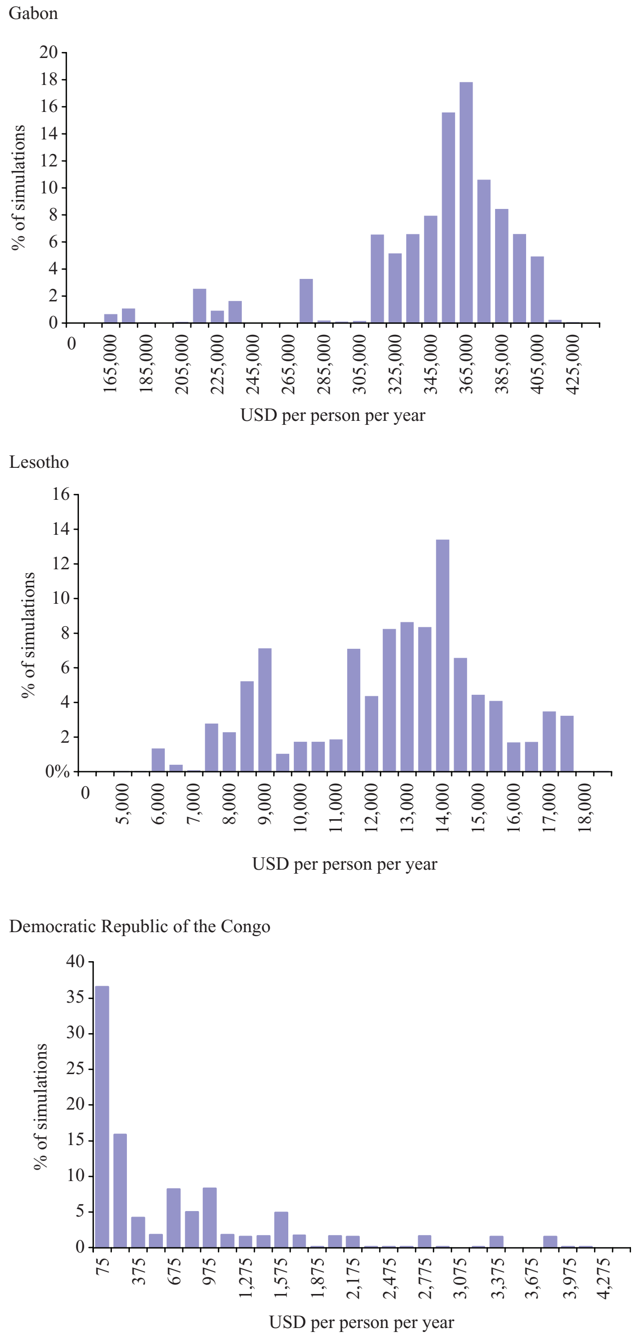

Figure 10. The probability density function of the per capita income in 2100 in the best off (Gabon), worst off (DR Congo) and median country (Lesotho)

income would be about USD 10,000/p/y in 2100 – 120 times the level in 2005. With climate change and civil war, income never exceeds USD 4,000/p/y. The DR Congo is firmly trapped in poverty and, if the model is correctly parameterized, there is little hope of escaping that trap because of climate change and civil war.

Combining the three probability density functions, we see that climate change and civil war have a limited effect on the economic development of some countries and, a devastating effect on others, and may or may not have a substantial effect on yet other countries. There is clear evidence that some countries are trapped in poverty by climate change and civil war. Other countries may fall into such a trap, while yet other countries face no such risk. The model thus has two solutions: a poverty trap and exponential growth.

We did not perform a sensitivity analysis on the model parameterization. Instead, we systematically varied the model parameters in a Monte Carlo analysis. Because of space limitations, we do not report results as a function of the values of the parameters. The model code and results are found with our replication data, so that readers can check such sensitivities for themselves. Qualitatively, the sensitivities are obvious. If the impact of climate change on civil war or the economy is smaller; if the risk of civil war or the vulnerability to climate change falls faster with development; or if the impact of climate change or civil war on development is smaller than assumed – then there is a lower risk of being trapped in poverty.

Discussion and conclusion

In this article, we construct a model of development, civil war and climate change. There are multiple interactions. Economic growth reduces the probability of civil war and the vulnerability to climate change. Climate change increases the probability of civil war. The impacts of climate change, civil war and civil war in the neighbouring countries reduce economic growth. The model has two potential poverty traps – a climate-change-induced one and a civil-war-induced one – and the two poverty traps may reinforce one another. We calibrate the model to sub-Saharan Africa and conduct a double Monte Carlo analysis accounting for both parameter uncertainty and stochasticity.

The parameter uncertainty is such that any particular numerical result is unreliable. However, systematic sensitivity analysis reveals the following, qualitative result. Although we use the SRES scenarios as our baseline, and thus assume rapid economic growth in Africa and convergence of African living standards to the rest of the world, the impact of civil war and climate change (ignored in SRES) are sufficiently strong to keep a number of countries in Africa in deep poverty with a high probability.

The following caveats apply. The model has simple, aggregate representations of complex and diverse

Downloaded from jpr.sagepub.com at Vrije Universiteit 34820 on May 2, 2013

phenomena. For example, we do not distinguish between civil wars of different intensities, and we treat climate change impacts as a deadweight loss to the economy. The model lacks a number of mechanisms that may affect our findings. These include human and physical capital, fertility, development assistance and interstate war. That said, the model is calibrated with realistic numbers and shows that conflict and climate change matter for development. This justifies repeating the analysis here with more complex models.

Replication data

The data replication files are available at http://www.prio.no/jpr/datasets. Appendices A, B and C present additional material on the regression analyses, model parameters and the FUND model, respectively. The data for the regression analyses (in Excel and Stata) and the Stata do-files are in regression.zip. The model code is in modelcode.zip, with auxiliary files in modelsupp1.zip and modelsupp2.zip. The graphs and the data behind the graphs are in figures.zip.

Acknowledgements

Research assistance by Jean Goggin, Michael Lucey and Emma O'Donoghue and discussions with Clionadh Raleigh, Joel Smith and Stephanie Waldhoff are gratefully acknowledged. Nils Petter Gleditsch and three anonymous referees had excellent comments on an earlier draft.

Funding

The US Environmental Protection Agency provided welcome financial support.

References

Acemoglu, Daron; Simon Johnson & James A Robinson (2001) The colonial origins of comparative development: An empirical investigation. *American Economic Review* 91(4): 1369–1401.

Acemoglu, Daron; Simon Johnson & James A Robinson (2002) Reversal of fortune: Geography and institutions in the making of the modern world income distribution. *Quarterly Journal of Economics* 117(4): 1231–1294.

Asteriou, Dimitrios & Simon Price (2001) Political instability and economic growth: UK time series evidence. *Scottish Journal of Political Economy* 48(4): 383–399.

Azam, Jean Paul; Augustin Fosu & Njuguna S Ndung'u (2002) Explaining slow growth in Africa. *African Development Review* 14(2): 177–220.

Barnett, Jon & W Neil Adger (2007) Climate change, human security and violent conflict. *Political Geography* 26(6): 639–655.

Barro, Robert J & Xavier Sala-i-Martin (1995) *Economic Growth*. Cambridge: MIT Press.

Bayer, Resat & Matthew C Rupert (2004) Effects of civil wars on international trade, 1950–92. *Journal of Peace Research* 41(6): 699–713.

Bergholt, Drago & Päivi Lujala (2012) Climate-related natural disasters, economic growth, and armed civil conflict. *Journal of Peace Research* 49(1): 147–162.

Bloom, David E; David Canning & Jaypee Sevilla (2003) Geography and poverty traps. *Journal of Economic Growth* 8(4): 355–378.

Bonds, Matthew H; Donald C Keenan, Pejman Rohani & Jeffrey D Sachs (2010) Poverty trap formed by the ecology of infectious diseases. *Proceedings of the Royal Society B: Biological Sciences* 277(1685): 1185–1192.

Bozzoli, Carlos; Tilman Brück & Simon Sottsas (2010) A survey of the global economic costs of conflict. *Defence and Peace Economics* 21(2): 165–176.

Brunnschweiler, Christa N & Erwin H Bulte (2009) Natural resources and violent conflict: Resource abundance, dependence, and the onset of civil wars. *Oxford Economic Papers* 61(4): 651–674.

Buhaug, Halvard (2010a) Climate not to blame for African civil wars. *PNAS* 107(38): 16477–16482.

Buhaug, Halvard (2010b) Reply to Burke et al.: Bias and climate war research. *PNAS* 107(51): E186–E187.

Buhaug, Halvard & Jan K Rød (2006) Local determinants of African civil wars, 1970–2001. *Political Geography* 25(3): 315–335.

Burke, Marshall B; Edward Miguel, Shanker Satyanath, John A Dykema & David B Lobell (2009) Warming increases the risk of civil war in Africa. *PNAS* 106(49): 20670–20674.

Burke, Marshall B; Edward Miguel, Shanker Satyanath, John A Dykema & David B Lobell (2010) Climate robustly linked to African civil war. *PNAS* 107(51): E185.

Butkiewicz, James L & Halit Yanikkaya (2005) The impact of sociopolitical instability on economic growth: Analysis and implications. *Journal of Policy Modeling* 27(5): 629–645.

Carmignani, Fabrizio (2003) Political instability, uncertainty and economics. *Journal of Economic Surveys* 17(1): 1–54.

Christensen, Jens Hesselberg; Bruce Hewitson, Aristita Busuioc, Anthony Chen, Xuejie Goa, Isaac Held, Richard Jones, Rupa Kumar Kolli, Won-Tae Kwon, René Laprise, Victor Magaña Rueda, Linda Mearns, Claudio Guillermo Menèndez, Jouni Raisaenen, Annette Rinke, Abdoulaye Sarr and Penny Whetton (2007) Regional Climate Projections. In S Solomon et al. (eds) *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press, 847–940.

Collier, Paul (1999) On the economic consequences of civil war. *Oxford Economic Papers* 51(1): 168–183.

Downloaded from jpr.sagepub.com at Vrije Universiteit 34820 on May 2, 2013

Collier, Paul & Anke Hoeffler (1998) On economic causes of civil war. *Oxford Economic Papers* 50(4): 563–573.
Collier, Paul & Anke Hoeffler (2005) Resource rents, governance, and conflict. *Journal of Conflict Resolution* 49(4): 625–633.
Collier, Paul; Anke Hoeffler & Dominic Rohner (2009) Beyond greed and grievance: Feasibility and civil war. *Oxford Economic Papers* 61(1): 1–27.
De Groot & Olaf J (2010) The spillover effects of conflict on economic growth in neighbouring countries in Africa. *Defence and Peace Economics* 21(2): 149–164.
Dell, Melissa; Benjamin F Jones & Benjamin A Olken (2008) *Climate Change and Economic Growth: Evidence from the Last Half Century*. Working Paper 14132. Washington, DC: National Bureau of Economic Research.
Dell, Melissa; Benjamin F Jones & Benjamin A Olken (2009) Temperature and income: Reconciling new cross-sectional and panel estimates. *American Economic Review* 99(2): 198–204.
Dixon, Jeffrey (2009) What causes civil wars? Integrating quantitative research findings. *International Studies Review* 11(4): 707–735.
Easterly, William (2002) *The Elusive Quest for Growth: Economists' Adventures and Misadventures in the Tropics*. Cambridge, MA: MIT Press.
Easterly, William & Ross Levine (2003) Tropics, germs, and crops: How endowments influence economic development. *Journal of Monetary Economics* 50(1): 3–39.
Eboli, Fabio; Ramiro Parrado & Roberto Roson (2010) Climate-change feedback on economic growth: Explorations with a dynamic general equilibrium model. *Environment and Development Economics* 15(5): 515–533.
Elbadawi, Ibrahim & Nicolas Sambanis (2000) Why are there so many civil wars in Africa? Understanding and preventing violent conflict. *Journal of African Economies* 9(3): 244–269.
Engle, Robert F & CWJ Granger (1987) Co-integration and error correction: Representation, estimation and testing. *Econometrica* 55(2): 661–692.
Fankhauser, Samuel & Richard SJ Tol (2005) On climate change and economic growth. *Resource and Energy Economics* 27(1): 1–17.
Fosu, Augustin K (2003) Political instability and export performance in sub-Saharan Africa. *Journal of Development Studies* 39(4): 68–82.
Gallup, John L; Jeffrey D Sachs & Andrew D Mellinger (1999) Geography and economic development. *International Regional Science Review* 22(2): 179–232.
Galor, Oded & David N Weil (1996) The gender gap, fertility, and growth. *American Economic Review* 86(3): 374–387.
Gartzke, Erik (2012) Could climate change precipitate peace? *Journal of Peace Research* 49(1): 177–191.
Gleditsch, Nils Petter (1998) Armed conflict and the environment: A critique of the literature. *Journal of Peace Research* 35(3): 381–400.
Gleditsch, Nils Petter; Kathryn Furlong, Håvard Hegre, Bethany Lacina & Taylor Owen (2006) Conflicts over shared rivers: Resource scarcity or fuzzy boundaries? *Political Geography* 25(4): 361–382.
Gyimah-Brempong, Kwabena & Marwa E Corley (2005) Civil wars and economic growth in sub-Saharan Africa. *Journal of African Economies* 14(2): 270–311.
Hallegatte, Stéphane (2005) The long time scales of the climate–economy feedback and the climatic cost of growth. *Environmental Modeling and Assessment* 10(4): 227–289.
Hallegatte, Stéphane & Daniel Théry (2007) Are the economic impacts of climate change underestimated? *Revue d'Economie Politique* 117(4): 507–522.
Hauge, Wenche & Tanja Ellingsen (1998) Beyond environmental scarcity: Causal pathways to conflict. *Journal of Peace Research* 35(3): 299–317.
Henderson, Errol A (2000) When states implode: The correlates of Africa's civil wars, 1950–92. *Studies in Comparative International Development* 35(2): 28–47.
Henderson, Errol A & J David Singer (2000) Civil war in the post-colonial world, 1946–92. *Journal of Peace Research* 37(3): 275–299.
Hendrix, Cullen S & Sarah M Glaser (2007) Trends and triggers: Climate, climate change and civil conflict in sub-Saharan Africa. *Political Geography* 26(6): 695–715.
Homer-Dixon, Thomas F (1994) Environmental scarcities and violent conflict: Evidence from cases. *International Security* 19(1): 5–40.
Horowitz, John (2009) The income–temperature relationship in a cross-section of countries and its implications for predicting the effects of global warming. *Environmental and Resource Economics* 44(4): 475–493.
IMAGE Team (2001) *The IMAGE 2.2 Implementation of the SRES Scenarios: A Comprehensive Analysis of Emissions, Climate Change, and Impacts in the 21st Century*, RIVM CD-ROM Publication 481508018. Bilthoven: National Institute for Public Health and the Environment.
Justino, Patricia (2009) Poverty and violent conflict: A micro-level perspective on the causes and duration of warfare. *Journal of Peace Research* 46(3): 315–333.
Kang, Seonjou & James Meernik (2005) Civil war destruction and the prospects for economic growth. *Journal of Politics* 67(1): 88–109.
Kjellstrom, Tord; R Sari Kovats, Simon J Lloyd, Tom Holt & Richard SJ Tol (2009) The direct impact of climate change on regional labor productivity. *Archives of Environmental and Occupational Health* 64(4): 217–227.
Koubi, Vally (2005) War and economic performance. *Journal of Peace Research* 42(1): 67–82.
Koubi, Vally; Thomas Bernauer, Anna Kalbhenn & Gabriele Spilker (2012) Climate variability, economic growth, and civil conflict. *Journal of Peace Research* 49(1): 113–127.
Link, P Michael & Richard SJ Tol (2011) Estimation of the economic impact of temperature change induced by a shutdown of the Thermohaline circulation: An application of FUND. *Climatic Change* 104(2): 287–304.

Downloaded from jpr.sagepub.com at Vrije Universiteit 34820 on May 2, 2013

Masters, William A & Margaret S McMillan (2001) Climate and scale in economic growth. *Journal of Economic Growth* 6(3): 167–186.

Murdoch, James C & Todd Sandler (2002) Economic growth, civil wars, and spatial spillovers. *Journal of Conflict Resolution* 46(1): 91–110.

Nakicenovic, Nebojsa & Robert J Swart, eds (2001) *IPCC Special Report on Emissions Scenarios*. Cambridge: Cambridge University Press.

Nordås, Ragnhild & Nils Petter Gleditsch (2007) Climate change and conflict. *Political Geography* 26(6): 627–638.

Raleigh, Clionadh (2010) Political marginalization, climate change, and conflict in African Sahel states. *International Studies Review* 12(1): 69–86.

Raleigh, Clionadh & Henrik Urdal (2007) Climate change, environmental degradation and armed conflict. *Political Geography* 26(6): 674–694.

Schollaert, Arne & Dirk van de Gaer (2009) Natural resources and internal conflict. *Environmental and Resource Economics* 44(2): 145–165.

Solow, Robert M (1956) A contribution to the theory of economic growth. *Quarterly Journal of Economics* 70(1): 65–94.

Strulik, Holger (2008) Geography, health, and the pace of demo-economic development. *Journal of Development Economics* 86(1): 61–75.

Theisen, Ole Magnus (2008) Blood and soil? Resource scarcity and internal armed conflict revisited. *Journal of Peace Research* 45(6): 801–818.

Tol, Richard SJ (2002a) Estimates of the damage costs of climate change – Part 1: Benchmark estimates. *Environmental and Resource Economics* 21(1): 47–73.

Tol, Richard SJ (2002b) Estimates of the damage costs of climate change – Part II: Dynamic estimates. *Environmental and Resource Economics* 21(2): 135–160.

Tol, Richard SJ (2011) Regulating knowledge monopolies: The case of the IPCC. *Climatic Change* 108(4): 827–839.

Urdal, Henrik (2005) People vs. Malthus: Population pressure, environmental degradation, and armed conflict revisited. *Journal of Peace Research* 42(4): 417–434.

van der Ploeg, Frederick & Steven Poelhekke (2010) The pungent smell of 'red herrings': Subsoil assets, rents, volatility and the resource curse. *Journal of Environmental Economics and Management* 60(1): 44–55.

van der Vliert E. (2008) *Climate, Affluence and Culture*. Cambridge: Cambridge University Press.

Welsch, Heinz (2008) Resource abundance and internal armed conflict: Types of natural resources and the incidence of 'new wars'. *Ecological Economics* 67(3): 503–513.

Wick, Katharina (2008) Conflict and production: An application to natural resources. *B E Journal of Economic Analysis and Policy* 8(1) (http://www.bepress.com/bejeap/vol8/iss1/art2).

Wick, Katharina & Erwin H Bulte (2006) Contesting resources: Rent seeking, conflict and the natural resource curse. *Public Choice* 128(3–4): 457–476.

Downloaded from jpr.sagepub.com at Vrije Universiteit 34820 on May 2, 2013

Appendix 1: Regression results

Table AI. Regression results for the occurrence of civil war

Symbol	*Description*	*Mean*	*StDev*	*z-stat*
α_1	Ln(per capita income)	–0.3266	0.1210	–2.70
α_2	Income growth	–0.06095	0.02975	–2.05
α_0	Time since previous conflict	–0.05934	0.00954	–6.22
α_0	Former colony of France	–1.256	0.559	–2.25
α_0	Social fractionalization	1.752	0.723	2.42
α_3	Number affected by drought	0.007352	0.004015	1.83
α_0	Intercept	0.9811	0.8683	1.13
	Pseudo R^2	0.221	N	956

Table AII. Regression results for the occurrence of drought

Symbol	*Description*	*Mean*	*StDev*	*z-stat*
β_1	Ln(per capita income)	–0.746	0.064	–11.7
β_2	Income growth	–0.000248	0.000099	2.51
β_0	Intercept	3.948	0.444	8.89
	Pseudo R^2	0.147	N	1347

Table AIII. Regression results for the number of people affected by drought (per million inhabitants), conditional on drought occurring

Symbol	*Description*	*Mean*	*StDev*	*z-stat*
β_1	Ln(per capita income)	–4.05	2.42	–1.68
β_0	Intercept	34.2	15.6	2.20
	R^2	0.012	N	240

(Collier et al. 2009) estimate a logit model of the probability of an outbreak of civil war. We re-estimated their model, adding variables that would be sensitive to climate change. Specifically, we added cereal production (total, wheat, maize, coarse grains), precipitation and the number of people affected by drought. We also added the number of immigrants and the stock of immigrants, which would be affected by sea level rise, among other things. Only the number of people affected by drought has a significant effect on the probability of civil war. We use a general-to-specific strategy with joint significance tests (Hendry, 1995) to find the model specification given in Table AI.

Table AII shows the results of a logit regression of the occurrence of drought (according to http://www.emdat.be/) on income and growth. Table AIII shows the results of a regression of the number of people affected by drought on per capita income.

CONOR DEVITT, b. 1985, MSc in Economics (Trinity College, Dublin); research professional at the Booth School of Business, University of Chicago.

RICHARD S J TOL, b. 1969, PhD in Economics (Vrije Universiteit, Amsterdam); Research Professor at the Economic and Social Research Institute, Dublin; Professor of Economics of Climate Change, Vrije Universiteit, Amsterdam; and Adjunct Professor of Economics at Trinity College, Dublin.

Downloaded from jpr.sagepub.com at Vrije Universiteit 34820 on May 2, 2013