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Article (Accepted version) (Refereed)

Original citation:
Lopez-Uribe, Maria del Pilar, Castells-Quintana, David and McDermott, Thomas K. J. (2016) *Geography, institutions and development: a review of the long-run impacts of climate change*. Climate and Development . ISSN 1756-5529

Geography, institutions and development: A review of the long-run impacts of climate change

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December 2015

Abstract

The links between climate change, economic growth and economic development have gained increasing attention over recent years in both the academic and policy literature. However, most of the existing literature has tended to focus on direct, short run effects of climate change on the economy, for example due to extreme weather events and changes in agricultural growing conditions. In this paper we review potential effects of climate change on the prospects for long-run economic development. These effects might operate directly, via the role of geography (including climate) as a fundamental determinant of relative prosperity, or indirectly by modifying the environmental context in which political and economic institutions evolve. We consider potential mechanisms from climate change to long-run economic development that have been relatively neglected to date, including, for instance, effects on the distribution of income and political power. We conclude with some suggestions for areas of future research.

Acknowledgements

We are very grateful for helpful comments on earlier drafts from Mintewab Bezabih, Declan Conway, Florence Crick, Sam Fankhauser, Stephane Hallegatte, Guy Jobbins, Hayley Leck, Annika Olsson, Helen Parker, Estelle Rouhaud, Maria Waldinger, and two anonymous referees. Any remaining errors are the sole responsibility of the authors. We acknowledge the financial support received by the UK Government's Department for International Development and the Canada's International Development Research Centre, under the Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA). The views expressed in this work are those of the creators and do not necessarily represent those of the UK Government's Department for International Development, the International Development Research Centre, Canada or its Board of Governors. A longer version of this article is available as Grantham Research Institute Working Paper No.198.

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Keywords:
Climate change, geography, institutions, economic growth, development

1. Introduction

The links between climate change and economic development have gained increasing attention over recent years in both the academic and policy literature. Understanding the effects of climate change on economic development is fundamental not only for the design of optimal mitigation and adaptation strategies but also in the design of broader strategies for long-term economic development.

The latest report from Working Group II of the Intergovernmental Panel on Climate Change (IPCC 2014), reflecting the state of the academic literature on climate impacts, focuses on the direct threats posed by climate change for, amongst other things, ecosystems, human health, agricultural productivity, and potential knock-on effects for issues such as food security, rural livelihoods and migration (e.g. Oppenheimer et al. 2014). We take this literature on climate impacts as a point of departure. Our intention in this paper is to step back from the immediate task of demonstrating economic impacts of climate change, identifying causal links and estimating the magnitude of potential effects – areas where the climate economics literature is perhaps currently most active – and instead, to consider potentially important directions for new research. In particular, we try to understand how the kind of impacts that have been identified in the literature – some of which are already occurring today - might affect the trajectory of economic development over many decades to come.

There has been extensive theoretical and empirical research on the *proximate* drivers of long-run economic growth. Factor accumulation (of physical and human capital) and technological progress have been identified as the main elements that account for growth differences across countries over time.[1] Trying to explain differences between countries in their rates of factor accumulation and technological progress has led to a focus in the literature towards understanding the *fundamental* determinants of economic development.[2] Among these, geography and institutions have probably attracted the most attention.[3] In this context, a key to understanding the long-run economic effects of climate change is to understand how climate change alters these deep-rooted determinants of long-run development.

In this paper we link the literature on the fundamental drivers of economic development with that on the impacts of climate change and show what the evidence suggests about the potential effects of climate change on long-run economic growth. There is, of course, more to economic development than just economic growth. Reducing inequalities and empowering marginalised groups, for instance, are also important and integral elements of economic development that do not necessarily go hand in hand with economic growth. For low-income countries, however, achieving sustained economic growth is essential to reduce poverty and increase aggregate living standards as well as to have the necessary resources to accomplish other development-related goals.[4] We do not review the direct effects of climate change on poverty here (see for example Olsson et al. 2014 and

Hallegatte et al. 2016), except to note that the uneven distribution of climate impacts – with certain locations and groups of people likely to be hit hardest – could have important effects on the fundamental drivers of development. Instead our focus is on the long-run effects of changing climatic conditions on economic development.

We consider potential mechanisms from climate change to long-run economic development that have been relatively neglected to date, including, for instance, effects on the distribution of income and political power. Our review concentrates on the empirical economics literature that attempts to measure climate impacts. However, we also briefly revisit the literature on institutions, on economic growth, and on fragile states, in order to highlight the possible mechanisms linking climate impacts to long-run economic development. Our review suggests that there are a potentially important set of dynamic interactions and feedback loops between institutions, climate (impacts and vulnerability) and development, which to date have been understudied. We pay special attention to the effects in low-income countries. These countries are anticipated to suffer disproportionately the most negative effects of climate change. They also tend to have relatively weak economic and political institutions, constraining their ability to cope with climate variability and shocks.

Climate change can affect the processes of economic development directly, by modifying relevant environmental conditions, with impacts for example on agriculture and labour productivity, disease environments, and via the effects of extreme weather events on capital formation. These mechanisms are now well established in the literature, albeit the evidence base in some cases remains relatively thin given the emerging nature of this research area. Aside from direct impacts, climate change might also affect development paths indirectly by altering the socio-political environment within which economic growth and development take place. We consider two specific channels through which climate change might affect development: institutions and conflict. Both of these have profound impacts on development outcomes. Each might be affected by climate change for example through climate's effects on poverty, inequality and the distribution of economic or political power, on the availability of resources, and on the movement of people. The potential for indirect effects from climate change to development is less well established in the literature to date. While there is a growing literature on climate and conflict (as reviewed for example in Dell et al. 2014), it tends to be mostly a-theoretical, lacking specific causal mechanisms. It is therefore difficult to draw policy conclusions from this literature in terms of how governments and international organisations can minimise the risk of climate change creating conflict.

Regardless of the strength of future mitigation efforts, our climate is already changing in response to anthropogenic forcing. Further warming will continue in response to past and current emissions, the effects of which on the global climate will be felt for decades to come (Solomon et al. 2007). On current trajectories future warming is likely to substantially exceed the 'dangerous' threshold of two degrees above pre-industrial levels (see e.g. World Bank, 2013). We know therefore that some adaptation will be required and that development strategies will need to take account of the potential effects of a changing

climate.

The literature on the economic impacts of climate change has been reviewed elsewhere, most recently in Dell et al. (2014). That review focussed on issues related to identification, crucial to establish reliable estimates of impacts. However, while identifying the magnitude of aggregate impacts is sufficient to motivate mitigation policies, the design of appropriate adaptation and climate-resilient development[5] strategies will require information on the precise causal mechanisms linking climate and economic outcomes, which is the focus of this review. Often, in the least developed countries, the main strategies to cope with climate change are developed in parallel to national development strategies or poverty reduction strategies (Fankhauser and Schmidt-Traub, 2010). By illustrating potentially important mechanisms of effect from climate change to long-run economic development, we hope our review might also be useful for informing climate-resilient development strategies.

The remainder of this paper proceeds as follows. In section 2 we focus on direct effects of climate change, analysing geographical determinants of economic development. In section 3 we focus on indirect effects. We start by looking at the role of institutions in the process of development (section 3.1 and 3.2). We then analyse institutional development, with a focus on conflict and political stability, as a relevant mechanism through which the effects of climate change can operate (section 3.3). In section 4, we conclude highlighting the main lessons from our review, policy implications and research gaps.

2. Geography and development

Geography clearly matters for development. The spatial distribution of economic activity (globally and within regions, countries, etc.) is far from random. Instead, human settlements and economic activity tend to cluster in particular locations. Some of the earliest towns and cities emerged on flood plains, benefitting from the available fertile soils and favourable climate. Roman and Medieval settlements tended to be based at militarily strategic sites (Michaels and Rauch, 2013). Modern-day economic activity is heavily concentrated on coasts and near (ocean-navigable) rivers, to avail of the gains from trade (Gallup et al., 1999, 2001).

The observed relationship between geography and development derives at least partly from differences relating to the fundamental characteristics of locations. For example, high transport costs, due to remoteness from markets, difficult mountainous terrains, or the fact of being land-locked, can significantly reduce the growth potential of countries by reducing trade opportunities (Gallup et al., 1999), investment and technology absorption (Henderson et al., 2001). Many of these factors are fixed (i.e. unchanging over time) and therefore will be unaffected by climate change. However, climate change is likely to result in changing risk profiles. This might have particularly important implications for economic development given the concentration of economic activity in specific locations, particularly on coasts, creating the potential for climate change to have costly impacts.

Geographical differences between locations, even if small, can lead to amplifying differences in the patterns of economic development. According to Galor (2005), variations in economic performance across locations today reflect initial differences in geographical factors and historical accidents manifested in variation in institutional, social, cultural, and political factors. According to New Economic Geography Models, spatial differences in economic development, whether between countries, between regions within countries, or between rural and urban locations, can be explained not just by natural geographical factors (inherent conditions of locations as discussed before) but also by the process of circular causation reinforcing agglomeration and development in initially favoured locations (Krugman, 1991, 1999; Puga and Venables, 1999; Henderson et al., 2001). Geographical factors give some places a head-start that magnifies over time and which helps us explain the vast spatial differences we see today. Hence, aspects of natural geography matter a lot, not because natural features of the landscape lead deterministically to the patterns of spatial development that we observe, but because they inspire self-reinforcing agglomerations (Krugman, 1999). This implies that small differences in terms of geographical characteristics can have long-lasting consequences and create *natural* patterns of divergence between different locations that are difficult to reverse.

On the one hand, it seems then that climate should matter a lot given the importance of differences in inherent productivity of locations and the possibility of these being reinforced by agglomeration effects. On the other hand, those same agglomeration effects might mean that future climate changes are unlikely to alter the *relative* spatial distribution of development. However this has important implications for adaptation (and development planning generally). The historical lock-in of spatial development patterns might create excessive exposure to natural hazards. This effect relates to the switching costs that societies would face if they were to change their historical spatial development, with the result that such patterns tend to persist even after substantial and damaging shocks such as war-time bombing (Davis and Weinstein, 2002) and large scale floods (Kocornik-Mina et al. 2015). For example, the fact that the earliest towns and cities emerged on flood plains obviously leaves them vulnerable to flooding risk. In the past, that risk may have been worthwhile to avail of the economic benefits inherent to those locations (in this case soil fertility). However, such location benefits may no longer be economically relevant, creating an excessive or unwarranted exposure to flooding risk. The difficulty of reversing patterns of spatial development therefore reinforces the need to consider future climate risk for development planning. Moreover, as those particular geographical characteristics more suitable for economic development are likely to change over time (for instance as transportation and communication technologies evolve or as economic structure changes) it also implies that sound interventions to foster specific advantages of locations can generate magnified benefits.

Urban centres deserve special attention. Cities are the drivers of modern economic growth (i.e. Jacobs, 1985; Glaeser, 2011). With a high concentration of assets (both physical and human) in urban locations, these areas are particularly important in terms of investment, innovation and technological change, all fundamental for economic development.

Disruptions to urban economies might therefore be particularly costly, not just in terms of the direct losses resulting from the destruction of assets, but also the potential knock-on effects for the wider economy and the rate of innovation and productivity growth, which ultimately determine an economy's long-run growth potential. Moreover, in spite of high congestion costs associated with increasing concentration in urban centres,[6] cities in many developing countries today continue to grow rapidly. While in many countries (like China) this is the natural by-product of structural change and greater opportunities in cities, in other countries (mainly in Sub-Saharan Africa) this happens also due to non-economic factors (Bloom et al., 2008), in particular as people are pushed away from rural areas due to diminishing resources, violent conflicts and in some cases, following natural disasters. In this latter case, there is rapid urbanisation without industrialisation and growth (see for instance Fay and Opal 2000; Kim 2008; Gollin et al. 2014). Climate change represents a risk in this regard as it creates an additional rural push factor driving people into cities (see e.g. Barrios et al., 2006; Henderson et al., 2014), as a result of climatic stress in rural areas. This climate-driven rural push factor adds to inefficient growth of urban areas (mega-cities), especially in places that are ill-equipped to cope with rapidly growing populations. Increasing agglomeration under deficient urban environments has been shown to reduce, rather than to increase, economic growth (Castells-Quintana, 2015). In this regard the provision of the necessary infrastructure arises not just as fundamental in terms of economic growth and development but also in terms of sustainable adaptation.

2.1. Direct effects of climate

Climate change represents a shift in the distribution of future weather, and can therefore distort both the mean and the variability of economically relevant weather variables, as well as potentially increasing the frequency and intensity of extreme weather events, leading to natural disasters (see e.g. IPCC, 2012). These changes are anticipated to exacerbate existing environmental challenges in poorer countries that already face hotter and more variable weather conditions (Stern, 2007; IPCC, 2013, 2014; World Bank, 2010, 2013), to which they struggle to adapt (e.g. Brooks et al., 2005, Barr et al., 2010).

It has often been observed that hotter countries tend also to be poorer (e.g. Gallup et al., 1999). However, in order to establish a causal effect of temperature (or other climatic variable) on income, it is necessary to look at changes over time, in order to isolate the effect of climate from other factors, which happen to be correlated with it. Several recent papers now explicitly focus on temperature changes over time. Looking at worldwide average temperatures and their relationship with economic growth, recent evidence suggests that, on average, a 1°C of global temperature increase reduces growth by 0.9 per cent (Bansal and Ochoa, 2009). This impact is found to be large for those countries that are closer to the Equator and negligible in countries at high latitudes. Looking at country-level temperature shocks, several papers find similarly negative effects on growth from higher temperatures, especially in poor countries (e.g. Dell et al., 2012; Brown et al., 2013). Jones and Olken (2010) find that higher temperatures in poor countries lead to large and negative impacts on the growth of their exports. Examining the industrial breakdown of the impacts of temperature, their findings show negative effects on agricultural exports and

light manufacturing exports (but little effect on heavy industry or raw materials production). Dell et al. (2012) find an analogous negative impact of higher temperature on industrial output. These findings indicate that climate change will have economic consequences beyond the agricultural sector. These effects might operate, for example, via the effect of temperature on productivity (see Martin et al., 2011; Advaryu et al., 2014), in line with arguments emphasising that factory workers are less productive when it is hot.[7] The negative effects of temperature shocks on economic activity seem to be permanent rather than transitory, substantially affecting the rate of economic growth and not only the level of output, with a 1°C increase in mean temperature in a given year reducing income per-capita by 1.4 per cent (Dell et al., 2012).

The effect of temperature is also felt in today´s developed countries; Deryugina and Hsiang (2014), using within-county variation in temperatures for the last decades, find significant effects of temperature on productivity in the United States – productivity of individual days declines roughly 1.7% for each 1°C increase in daily average temperature above 15°C.

Several other papers focus on (changes in) rainfall patterns as a consequence of a changing climate (e.g. O'Connell and Ndulu, 2000; Barrios et al., 2010; Brown and Lall, 2006; Brown et al., 2013). In the particular case of Africa, a significant decrease in rainfall levels has been observed since the 1960s (Nicholson, 2000, 2001). Given the importance of the agricultural sector in Africa, and the relevance of rainfall for agricultural productivity, this decline might have important consequences for economic growth, as has been suggested by Bloom and Sachs (1998) and Collier and Gunning (1999). Indeed, O'Connell and Ndulu (2000) found significant lower long-run economic growth rates in Africa in those countries with a higher proportion of dry years. Similarly, Barrios et al. (2010), studying the relationship between rainfall and economic growth for 22 African and 38 non-African countries over the period 1960-1990, provide evidence on the adverse effects on economic growth rates of the general decline in rainfall in Africa during recent decades (controlling for effects from temperatures, which they find not to be significant). This effect of rainfall was not found for other developing countries. According to the results of simulations carried out by these authors, if rainfall in Africa had remained at previous levels, the current gap in GDP per capita relative to other developing countries could have been between 15 per cent and 40 per cent lower.

2.2. Climate change and economic performance: Mechanisms

A caveat in relation to most of the empirical literature mentioned here is that it tests 'reduced form' relationships – i.e. looks directly at the relationship between climate variables (e.g. temperature or rainfall shocks) and economic growth or output, without formally testing the causal mechanisms connecting climate and the economy. Several channels allow for climate change to directly affect economic performance. In what follows we discuss some of the most likely mechanisms.

A. *Agriculture and labour productivity*

Parsons (2014) explains how changes in the temperature can reduce labour productivity. When heat exposure is high, changes in the air temperature not only affect body temperature but also productivity during work time. Physical work activities add surplus heat production to the human body, so when the air temperature is higher than 37 C, the heat transfer goes into the body but at high temperatures and humidity level, and evaporation of sweat in order to reduce the body heat is less effective. In these scenarios, sweating continues but there is no body heat loss via evaporation, leading to a decrease in physical performance. Hence, deteriorating climatic conditions can reduce not only agricultural productivity (Deschenes and Greenstone, 2007; Guiteras, 2009; Schlenker and Lobell, 2010; Feng et al., 2010)[8] but also labour productivity in industrial sectors that lack efficient cooling systems (Martin et al., 2011; Advaryu et al., 2014; Dunne et al 2013, Zander et al 2015). And low agricultural productivity, for instance due to poor soil quality, lack of fresh water, prevalence of pests, and in general less suitable conditions for the spread and improvement of agriculture, not only reduces agricultural output but it can also retard industrial development (e.g. Diamond, 1997).

Some works have tried to estimate the magnitude of the effect of changes in temperature on labour productivity. Dunne et al (2013) have estimated that during the last few decades, heat stress has reduced labour capacity to 90% during peak months, being the tropical and mid-latitudes regions the most affected areas. However, the impact of these changes will also depend on other factors such as climate sensitivity, future population distributions, CO2 emissions and technological change. Zander et al (2015) highlight the importance of adopting measures to reduce the heat effect. They estimate the costs of absenteeism and work performance due to heat in Australia during 2013/214 and calculate an annual cost of US$655 per person and around US$6.2 billions for the Australian workforce (0.33-0.47% of Australian GDP).

B. *Disease environments and population dynamics*

Second, changing weather patterns might have longer-term development effects by altering disease environments, both via changes in environmental conditions and via the effects of weather patterns on migration and urbanisation patterns. Particularly harsh disease environments, for instance characterised by a high prevalence of malaria (Gallup and Sachs, 2001; Sachs and Malaney, 2002), can significantly reduce productivity in several ways (see also Masters and McMillan, 2001). A harsh environment affects health (Deschenes and Greenstone, 2011) and reduces work capacity and productivity directly (Seppanen et al., 2006; Sudarshan and Tewari, 2014). Diseases also increase child mortality and lower life expectancy, which in turn increases fertility and harms incentives to acquire and accumulate human capital, creating regional-specific patterns of demographic transition, leading ultimately to slower development of regions with unfavourable environmental conditions (Strulik, 2008).

Climatic conditions can also affect population dynamics and migration patterns, in turn affecting the pace and form of structural change and urbanisation processes (e.g. Barrios et al., 2006; Henderson et al., 2014).[9] One risk of the concentration of population in urban areas is that urban agglomerations are particularly susceptible to flooding and heat stress,

and allow more rapid spreading of diseases such as cholera – especially where basic services such as access to water and sanitation facilities are underprovided.

C. *Extreme weather events and the depreciation of capital:*

Climate-related shocks, such as extreme weather events, can also depreciate the stock of physical, human and environmental capital (Hochrainer, 2009), and damage key infrastructures (Heltberg et. al., 2008). Likewise, climate-related shocks also modify saving and investment decisions, not just of domestic agents (Hallegate, 2014) but also of potential foreign investors (Escaleras and Register, 2011), affecting both physical as well as human capital accumulation.[10]

Looking at the empirical evidence, several papers confirm that natural disasters represent setbacks for economic growth (e.g. Hsiang, 2010; Hsiang and Narita, 2012; Hsiang and Jina, 2014; McDermott et al., 2014). Although it had previously been suggested that disasters could have a positive impact on economic growth (Skidmore and Toya, 2002), recent literature shows that such positive effects would only occur in response to relatively moderate disasters (Loayza et al., 2012). Positive effects might be associated with reconstruction and the opportunity to renew and upgrade installed capital, infrastructure and existence technologies. However, severe disasters, especially those that affect poor countries, are significantly associated with lower economic growth (Raddatz, 2009; Loayza et al., 2012). According to Loayza et al. (2012) different disasters have differentiated effects on growth depending on the economic sector; droughts and storms are found to have the strongest negative effects for agricultural productivity. Given that the elasticity of poverty to growth generated in the agricultural sector is higher than for other sectors of the economy, these disasters can be expected to affect the poor disproportionately.

3. Indirect mechanisms: Climate change and institutional development

There are at least two main reasons to focus on institutional development in the analysis of the effects of climate change. First, the evidence reviewed so far appears to indicate that geography (including locational fundamentals and climate) matters a lot for economic development, particularly in its early stages, but perhaps less so as modern economic growth 'takes off'. This is also reflected in the empirical evidence on the impacts of climate shocks and disasters, which appear to have important macroeconomic (and growth) impacts in poorer countries, whereas similar events tend not to disrupt the economies of relatively wealthy developed nations. There is thus, perhaps, some threshold of development - in terms of income or institutional quality - below which climate will continue to exert a significant direct influence on economic development.[11] In particular, many low-income countries, especially in Sub-Saharan Africa, but also some middle-income countries, have states that are unable to perform minimum functions expected from modern sovereign states. These states are defined as "weak", "fragile" or even "failed" or "collapsed" (Zartman, 1995; Torres and Anderson, 2004).[12] The combination of weak institutions and a lack of basic economic, financial and physical infrastructure, result in the difficulty faced by many of these poor countries in escaping from poverty (see e.g.

Collier et al., 2008; Dercon, 2012), but also in their relatively low adaptive capacity (see e.g. Fankhauser and McDermott, 2014) and their subsequent economic vulnerability to climate shocks.

Second, there is increasing evidence that beyond direct effects, climate (and geography in general) can also affect the possibilities for development by affecting the socio-political and institutional environment in which development takes place. Climate might have an effect on state fragility itself, for example as a catalyst of conflict or as a factor increasing the extent and intensity of existing conflicts. There is increasing evidence on how geographical factors influence institutional development (Engerman and Sokoloff, 1997; Acemoglu et al., 2001, 2002; Rodrik, 2004; Acemoglu and Robinson, 2012) and the likelihood of conflict (Miguel et al., 2004; Hsiang et al., 2011; Dell et al., 2014).

In this section we analyse the role of geography in the socio-political and institutional environment to better understand potential indirect effects of climate change in the process of economic development and economic growth. We focus on institutional capacities and the potential for climate to alter the conditions under which institutions evolve, including the effects of climate on conflict.

3.1. Geography, institutions and development

Institutions clearly matter greatly for economic development. The relevance of institutions in the prosperity of nations has been highlighted since the beginnings of modern economic thought - from Smith (1776) to Veblen (1899), Commons (1924), Galbraith (1958), Myrdal (1968) and many others.[13] Since then our knowledge of how institutions shape and interact with economic development has substantially increased. But our understanding of how institutional arrangements evolve over time and what factors contribute to successful institutional reform in different contexts remains somewhat limited. It appears that geography, broadly defined to include climate, physical geography and resource endowments, may have played an important role in the emergence of modern institutions and the apparently crucial distinction between locations that evolved *extractive* versus *inclusive* institutions. Acemoglu et al. (2001) famously used variation in disease environments to explain the emergence of extractive institutions in some locations (e.g. Africa) and inclusive institutions in others (e.g. North America). It does not automatically follow, however, that *climate change* should have any great influence on the future development of economic and political institutions. Certainly it seems unlikely, barring catastrophic scenarios, that climate change will have any major bearing on institutional arrangements in places with established stable and inclusive regimes.[14] On the other hand, in locations where power, institutions, and the rule of law are more contested – i.e. in fragile states – subtle changes to political incentives resulting from changes in environmental conditions, changes in the value of natural assets, or disputes over resources could generate non-negligible effects on institutional quality.

Other potential mechanisms from climate (change) to institutional change, discussed in more detail below, include; the reinforcement of existing social and economic inequalities

due to the unequal distribution of anticipated impacts from climate change; disruptions to long-run investments, including the provision of public goods and services, and human capital investments following weather shocks that reduce output or destroy assets; and disruptions to political stability, in the form of the (at times violent) contesting of power following income shocks. For less developed regions generally, their greater vulnerability to climate change and relatively weak existing institutions could make the threat of climate change more relevant for institutional development. Understanding the emergence of institutions is therefore crucial for understanding the potential role of climate (change) for long-term economic development.

In spite of their crucial importance in defining the possibilities for economic development, institutions remain poorly understood. One difficulty is that institutional development is highly endogenous to the evolution of economic life; institutions shape economic development as much as the evolution of economic life shapes the evolution of institutions. A number of studies have attempted to identify causal links from institutional quality (usually looking at measures reflecting the quality of economic institutions) to economic performance and long-run prosperity (Mauro, 1995; Engerman and Sokoloff, 1997, 2000; Hall and Jones, 1999; Acemoglu et al., 2001, 2002; Rodrik et al., 2004).[15] But country-wide proxies for institutional quality are far from perfect, and cross-country econometric analysis of the role of institutions on economic development based on these proxies has several limitations and can even be misleading.[16] Likewise, despite the clear association between institutional development and economic development, advocating for single-recipe institutional reforms as a straightforward way of achieving economic development is simplistic and potentially risky (Bates (2006), for example, links political reform to increased likelihood of conflict and violence in Africa).

For poor countries the assessment of institutional quality becomes difficult and policy prescription becomes overwhelming, as most indicators of institutional quality are hardly met. In this context several authors have suggested that countries should focus on achieving "good enough governance" and "second-best institutions", looking at specific reforms that are essential, feasible, easier to implement, and that take into account the stage of development as well as interactions with initial conditions and context-specific institutional arrangements already in place (Grindle, 2004; Rodrik, 2008). In particular, fostering economic growth and improved economic opportunities for the majority of the population, even under sub-optimal institutional arrangements, has been shown to potentially play a fundamental role in fostering institutional change itself (Rodrik, 2008).[17] Societies face a set of "institutional opportunities" which improves as countries emerge from poverty and accumulate human, social and physical capital (Djankov et al., 2003; Glaeser et al., 2004). Climate change not only has a direct impact on economic growth (as shown in section 2), but it also shapes the "institutional opportunities" that each country faces. In this context, climate change should be taken into account in the design of key reforms to spur growth as well as in the design of new, context-specific institutions.

Instability, conflict and economic development

Instability and persistent (violent) conflict are two of the most worrying and common elements characterising fragile states (Rotberg, 2003), deterring their opportunities for prosperity: conflict and political instability have been found to significantly hamper growth and economic development (Gupta, 1990; Barro, 1991; Knack and Keefer, 1995; Alesina and Perotti, 1996; Easterly and Levine, 1997; Rodrik, 1999; Sala-i-Martin et al., 2004; Butkiewicz and Yanikkaya, 2005).[18] Furthermore, instability and conflict have been identified as a powerful trap for poverty and underdevelopment, leading to lower economic development (Collier, 2007). Underdeveloped countries are in turn more prone to conflict and instability. Indeed, countries in conflict are among the worst Millennium Development Goals (MDGs) performers, frequently regressing on key indicators, with the direct impacts of warfare usually accompanied by a weakened economy and government capacity, leading to lower development prospects, in some cases pushing countries into a downward spiral (UNDP, 2011). However, theories about state formation and failure consider conflict as an integral element of countries' institutional development (see Di John, 2010). Institutions are defined by conflict of interests and the distribution of power within societies. Climate change can alter the economic opportunities of different groups and trigger conflict over natural resources and the distribution of power, therefore likely playing a role in the definition of institutions. It then becomes essential to better understand how climate change affects different groups, and the mechanisms linking these effects to conflict propensity and intensity and institutional development.

3.2. The (potential) role of climate change

The possibility of strong and long-lasting effects of climate change and climate-related shocks in the process of development has been analysed in historical perspective (Davis, 2002; Fagan, 2005, 2009).

There is evidence that significant changes in climate (temperature and rainfall patterns) already had important societal impacts in the distant past. For instance, Dixit et al. (2014) report a connection between weakening of the Indian summer monsoon and de-urbanisation in India around 4,100 years ago, in a time of severe aridification, which affected several Early Bronze Age populations. Similarly, Pederson et al. (2014) suggest that unusual above-average moisture in central Mongolia promoted high grassland productivity and favoured the formation of Mongol political and military power that facilitated the emergence of the vast 13th century Mongol Empire. Although the changes in temperature and rainfall patterns analysed in these papers occurred before human-induced climate change, the evidence about their impacts reinforces the relevance of changing climatic patterns today.[19]

Looking at modern times, there appears to be some correlation between weather conditions and conflict globally. For instance, drylands are among the most conflict-prone regions of the world. In 2007, 80 percent of major armed conflicts worldwide occurred in drylands (UNDP, 2011). Although such correlations tell us nothing about causation - as in the debate over the relationship between climate and development - there is now a growing empirical literature assessing possible climatic determinants of conflict (see Homer-Dixon,

1991; Dell et al., 2014). It has even been argued that changing climatic conditions can lead to the collapse of societies, as a result of increased conflict associated with environmental stress (Diamond, 2005).

Looking at global patterns, Hsiang et al. (2011) have demonstrated that civil conflicts are indeed associated with climatic variation, based on observations of a relationship between El Niño/Southern Oscillation (ENSO) fluctuations and annual conflict risk. A number of papers link periods of drought with increased conflict (e.g. Couttenier and Soubeyran, 2013; Maystadt and Ecker, 2014; and Maystadt et al., 2013). Similarly, Burke et al. (2009) find that hotter years are associated with increased incidence of civil war in Africa in the late 20th century. Hendrix and Salehyan (2012) conclude that rainfall deviations in either direction may be related to conflict, but that violent events are more responsive to heavy rainfall (which may cause subsequent scarcity through the effect of flooding on agricultural yields).

Climate change is likely to modify the environmental context and the opportunities available to individuals and societies, potentially reinforcing material inequalities as well as influencing the distribution of power within societies. In this way, climate change can influence not only the probability and intensity of conflict but also institutional arrangements and therefore institutional development. However, empirical evidence in this regard remains limited, with few papers explicitly studying the relationship between climate change and political change. This appears to be a significant research gap.

A. *Poverty and income shocks*

Burke and Leigh (2010) and Bruckner and Ciccone (2011) are among the first to test empirically the relationship between climate and institutional change. Although these works use changes in climatic conditions as an exogenous shock to output, their conclusions seem to support the idea that weather shocks may lead to institutional change; in this case democratisation. In both papers, the mechanism proposed is via output: negative rainfall shocks open a 'window of opportunity' for democratic improvement because it translates into a transitory negative GDP shock and a lower opportunity cost of contesting power. In contrast to these findings, Dell et al. (2012), highlighting a similar mechanism, show that adverse temperature shocks might increase the probability of irregular leader transitions such as coups, resulting in negative impacts on economic growth. They support their results on the previous empirical evidence that riots and protests are more likely in warmer weather (Boyanowsky, 1999) and, in addition, on the idea that economic impacts of higher temperatures might provoke dissatisfied citizens to seek institutional change – in this case with negative results for the economy.

These somewhat contrasting results illustrate the need for a greater understanding of the mechanisms that potentially link climatic conditions to institutional change. The authors cited above emphasise the effects of weather shocks on income, leading to changes in the opportunity cost of contesting power. However, such a mechanism potentially represents a double-edged sword for institutional development; on the one hand, the opportunity to contest power offers a possible 'window of opportunity' for institutional improvement (e.g.

through removal of an autocratic regime). On the other hand, contesting power might involve (violent) conflict, with no guarantee of an improved outcome.

The role of income shocks is also prominent in the literature on climate and conflict. For example, contest models of conflict (e.g. Hirshleifer, 1988, 1989; Garfinkel, 1990; Skaperdas, 1992) highlight the association between poverty and conflict through individuals' incentives to maintain order, and therefore predict higher likelihood of conflict in poorer countries or regions.[20] This mechanism underlies many of the empirical studies of climate and conflict to date (see Dell et al., 2014, for a review of this empirical literature). Miguel et al. (2004) were among the first to propose and test the relationship between weather shocks and conflict, finding that negative economic shocks, caused by decreases in the level of rainfall, tend to trigger conflict. Since then, this strand of literature has expanded rapidly, with numerous papers finding significant links between weather variation and conflict. However, these findings have not been uncontroversial, and there remains some uncertainty over the precise causal mechanisms linking climate and conflict and the most relevant climatic variables.

In a review of the arguments for climate variability to influence conflict though economic growth, Koubi et al. (2012) find no evidence of significant effects of climate variability on growth. Miguel and Satyanath (2011) similarly argue that for the period 2000-2009 there is no strong relationship between rainfall and growth for African countries, implying that rainfall might not be used as an instrument to study the effect of economic shocks on conflict risk. Sarsons (2011) has also found problems using rainfall as a measure of economic shocks. Whereas he supports previous findings in rain-fed districts in India (Bohlken and Sergenti 2010), he argues that in dam-fed districts wages are less sensitive to rain shocks (although he finds that rainfall might still affect conflict through a channel other than income in these districts). Dell et al. (2014) propose different reasons for the diverse findings in the literature: omitted fixed effects, differences in the way both weather and conflict are parameterised, and noisy estimates make it difficult to reach conclusions about the effect of rainfall fluctuation on conflict risk.

According to Chassang and Padro-i-Miquel (2008, 2009) the likelihood of conflict increases after negative shocks while it decreases with the expectations of higher incomes. Hence, lower and volatile growth can lead to higher risk of conflict. As climate-induced income shocks hit the poor in a disproportionate way - as discussed elsewhere in this paper - climate change might affect the likelihood (and severity) of conflict by reinforcing existing poverty dynamics.

For poor countries, climate-induced income shocks have been analysed mostly looking at dynamics in rural areas. Variations in agricultural production and cattle herding are among the most common mechanisms proposed to explain how temperature and rainfall fluctuations might affect conflict risk through income shocks (Miguel et al., 2004; Mehlum et al., 2006; Chaney, 2010; and Ciccone, 2011, for rainfall, and Burke et al., 2009, for temperature). Negative economic shocks driven by the decrease of rainfall levels have been found to increase Muslim-Hindu riots in Indian states (Bohlken and Sergenti, 2010) as well

as communal conflict in subnational African regions (Fjelde and von Uexkull, 2012). Using data from East Africa, Raleigh and Kniveton (2012) argue that civil war is more likely in extreme dry conditions whereas wet conditions are more associated with non-state conflict. In a study for Somalia, Maystadt and Ecker (2014) suggest that local livestock markets are the primary channels through which droughts fuel conflict, and that livestock price downturns and losses in herder's income lower resistance to engage in conflict and decrease the opportunity costs of conflict participation.[21]

A low opportunity cost of fighting, usually associated with low levels of income per capita, has often been identified as one of the main determinants of the probability of conflict (Collier and Hoeffler, 1998, 2004; Miguel et al., 2004; Besley and Persson, 2008; Collier et al., 2009).[22]

Negative economic shocks, associated with rainfall, can have long-term effects through mass rebellions. Kung and Ma (2014) suggest that suboptimal rainfall may have triggered peasant rebellions in China (although these shocks might have been overcome by the appearance of Confucianism). In this line Jia (2013) reports that droughts indeed increased the probability of peasant revolts in China by 0.7 per cent.

In a similar argument, and looking at long-term trends, Zhang et al. (2007) show how fluctuations of war frequency and population change in the pre-industrial era followed the cycle of temperature change; long-term climate change directly affects land-carrying capacity (agricultural production) and can lead to unrest, conflict, famines and epidemics. Waldinger (2013) also finds a significant relationship between climatic trends and peasant revolt during the French Revolution – with higher summer temperatures and lower winter temperatures associated with increased incidence of revolt. Tol and Wagner (2010) similarly find that colder times were associated with increased conflict in Europe. In a European context (i.e. in a relatively cold climate), periods of colder weather may have resulted in worse growing conditions, and a resultant negative shock to incomes.[23]

However, income shocks are not the only mechanism that potentially links climate change to institutional change and/or conflict. In the rest of this section, we discuss other potential mechanisms, relying mainly on theoretical arguments, given the lack of empirical work (or very scarce evidence) in this area to date.

B. *Inequalities and the distribution of power*

The distribution of power also matters for the quality of institutions and governance as well as for conflict. The literature reviewed previously on institutions highlighted the relevance of inequalities and the distribution of power.[24] In this literature inequalities appear as critical in the development and persistence of institutions as in any scope for institutional change; when extreme, inequality can become an important obstacle for successful institutional reform, but it is also true that inequality might have been one relevant factor behind political revolution, for instance in the extension of the franchise in the 19th century in several European countries (Acemoglu and Robinson, 2000; Przeworski, 2009; Aidt and Franck, 2015). The literature on conflict has also highlighted the role of

distribution; Acemoglu and Robinson (2001, 2010) model elites as competing with the poor for control of the state and bargaining to accommodate the rest of the society by extending the voting franchise in periods when there are real threats of revolt. Ray (2009) models the emergence of conflict based on the impossibility to arrange transfers that satisfy all groups. His model predicts a high likelihood of conflict in divided societies - either by class, geography, religion, or ethnicity. Ethnic polarisation (rather than fractionalisation) has also been highlighted as a significant determinant of conflict; in societies where a large ethnic minority faces an ethnic majority severe conflict is more likely to arise (Montalvo and Reynal-Querol, 2005).[25] Thus, where climate change is expected to reinforce existing inequalities, this could have knock-on effects for the quality of institutions and ultimately conflict.

C. *Resources, incentives and information*

It has been suggested that geography (including climate) matters in the choice of economic policy itself (Gallup et al., 1999). The logic is that the political economy of policy formation depends on the incentives faced by policy-makers. Where growth prospects are weak, the incentive to pursue pro-growth, inclusive economic policies may be weaker than the incentive to pursue 'extractive' type policies that produce short-term benefits for those in power. Alternatively, the decline of aggregate output can diminish government revenues, making the state invest less in state capacity and security. In any case, climatic conditions, by modifying the growth prospects of poorer nations, might also lead to endogenously worse economic policies.

This reasoning is similar in spirit to some of the *resource curse* literature, where natural resources have been identified as playing a role in conflict risk (e.g. Fearon and Laitin, 2003). Natural resource revenues represent a bigger (and more easily appropriable) prize in case of success and also a source of finance for fighting activities. Besley and Persson (2008) also highlight the role of the nature of the prize and how it will be distributed given institutional constraints, the technology for fighting and the likely allocation of power in the absence of an insurgency. As a consequence, not only does conflict diminish state capacity, but it is only when political institutions provide insufficient checks and balances or enough protection for those excluded from power that other determinants of conflict, such as climate, aid or external shocks, become significant determinants increasing the likelihood of conflict (Besley and Persson, 2009).

Sachs and Warner (2001) show how natural resource countries tend to miss-out on export-led growth. Natural resources can also make the government less accountable to the population (as relying on natural resource extraction rather than on taxation). This suggests a further political-economy risk associated with climate change; i.e. that climate finance flows to developing countries could make their governments less politically accountable.

Another related set of conflict models looks at the problem of commitment (Walter, 1997; Garfinkel and Skaperdas, 2000; Powell, 2006; McBride and Skaperdas, 2007). According to

these models civil war is more likely to occur when there are limits to conflict resolution and contract enforcement along with a high probability of a shifting distribution of power. The distributional effects of climate change might therefore play a role in contributing to the risk of civil conflicts.

Economic inequalities (Fearon, 2007) and frustration (Davies, 1962; Gurr, 1971; Paige, 1975; Scott, 1976; Petersen, 2001; looking at agrarian revolutions in the 1960s and 1970s) clearly play a strong motivating role in many conflicts. However, nonmaterial incentives, including grievances and vengeance, might better describe proximate explanations of conflict (Roemer, 1985; Wood, 2003). Climate change might also play a role here when grievances over resources (e.g. water, access to land, grazing rights etc.) are generated by changing environmental conditions.

Finally, recent literature distinguishes between motivation of conflict and feasibility of conflict. On the one hand, motivation can be driven by root causes, whether historical, political or socio-economic, with poverty, inequality and political exclusion being commonly discussed in this regard. Feasibility, on the other hand, may be driven by circumstances distinct to motivation, and has been the focus of several authors (Hirshleifer, 2001; Collier and Hoeffler, 2004; Weinstein, 2005; Collier et al., 2009). According to these authors, conflict will be more likely to occur where it is financially and militarily feasible, and this in turn is likely to depend on a combination of geographic and demographic factors, as well as on the presence of an ineffective state.

D. *Migration and human capital*

One important way in which climate shocks can increase the likelihood of conflict is by inducing migration. In fact, one of the main security challenges brought about by climate change (through increasing the frequency and severity of climate-related natural disasters as well as through affecting natural resources and weather conditions) is the rise in mass migrations. Mass waves of 'climate refugees' are regularly cited as one of the potential risks of runaway (unabated) climate change. For example, Myers and Kent (1995) forecast 150 million environmentally-induced refugees by 2050 (although according to Gemenne (2011) these estimates appear to lack empirical support). While the numbers may be speculative, the risks are not so easily dismissed. It is notable that the security/military community takes these threats seriously, and conducts its risk assessments on the basis of considering multiple plausible future scenarios. For instance, according to the Campbell et al. (2007) report, the disappearance of low lying coastal lands could conceivably lead to massive migrations - potentially involving hundreds of millions of people - and trigger major security concerns and spike regional tensions.[26]

Regardless of its impacts on the number of future migrants, climate change also has the potential to alter the quality of migration patterns (Jäger et al., 2009). While the displacement of people following natural disasters is typically temporary, over short distances and along well established routes (McMichael et al., 2012), climate change has the potential to generate extreme events, or combinations of events, that would overwhelm existing coping mechanisms, leading to larger-scale, longer-term and longer-distance

migrations that are likely to be less organised or planned. These irregular and/or unexpected migrations pose the greatest threat to stability and security (Foresight, 2011).

Hidalgo et al. (2010) examine the link between weather conditions and conflict looking at land invasions. Exploring municipal-level data from 1988 to 2004 in Brazil and using rainfall variation as a proxy of adverse economic shocks, they find that these shocks cause the rural poor to invade large landholdings. Nevertheless, their findings exhibit considerable heterogeneity by land inequality and land tenure systems. In highly unequal municipalities, negative income shocks (measured as climate shocks) cause twice as many land invasions as in municipalities with average land inequality.

In section 2.2 we saw potential direct effects of climate change on the disease environment. Another potential risk is the threat to human health posed by large-scale population movements: "[T]he health risks posed by climate-related population movements are likely to become a major source of human suffering, disability, and loss of life—an outcome that, currently, appears more likely than the much-debated possibility of increased violent conflict or state failure (Kolmannskog, 2008)." – McMichael et al. (2012, pp.646-7). But these are not distinct (separate) threats. On the contrary, migration, disease patterns and violent conflict interact in complicated ways, and potentially reinforce each other. In the context of agriculturally-marginal semi-arid zones of West-Central Africa, Miller (1982) documents historical links between climate change and patterns of settlement and migration, with an emphasis on the effects of climate induced scarcity on migration, disease, and migration-induced conflict.

Finally, and as mentioned before, the opportunities for institutional development depend on levels of human capital (Djankov et al., 2003; Glaeser et al., 2004). Thus, another mechanism through which climate change can deter institutional development is, of course, by hindering human capital accumulation.

E. *Extreme weather events*

Few papers explicitly focus on the link between natural *disasters* and conflict. Although this literature is not extensive, some writings on environmental security and "political ecology" provide useful arguments for understanding how natural disasters might impact societies and how these events might affect conflict risk through their impacts on social variables, such as migration, as well as on economic variables. Nel and Righarts (2008) use data for 187 political units for the period 1950-2000 to explore this question and find that natural disasters significantly increase the risk of violent civil conflict both in the short and medium-term, particularly in low- and middle-income countries that have high levels of inequality, mixed political regimes, and sluggish economic growth. However, these conclusions appear to be contradicted by Slettebak (2012) who finds that countries that are affected by natural disasters have a lower risk of civil war. Different explanations are given: one explanation comes from the *sociology of crisis* and is related to the idea that people tend to unite in adversity. Another explanation suggests that disasters provide an opportunity for governments to display both their competence and incompetence, so the negative effect of disasters on conflict can be read as a way used by the government to improve

their popularity, reducing the pool of potential recruits for insurgent organisations. Among this group of literature, Bergholt and Lujala (2012) find that natural disasters have a negative effect on economic growth, but this does not translate into an increased risk of conflict.

4. Conclusion and policy implications

In this paper we have studied the role of climate change in the process of long-term economic growth and development, reviewing the literature on the determinants of economic development and analysing the role that climate change can potentially have in this regard. We have looked at both potential direct and indirect effects of climate change, focusing on implications for low-income countries. This broad approach allows us to better understand in an integrated way the different effects of climate change on long-term development and frame the adaptation discussion in terms of climate-resilient economic development, as well as identifying policy implications. In particular we have analysed the role of geography and institutions, with a focus on conflict and instability, in the process of development. In each case we have looked at possible effects of climate change and climate-related shocks, as well as at the empirical evidence on these effects and existing gaps in the literature.

Looking at the direct effect of climate, we have described how climate change can affect the processes of long-run economic growth and development in different ways. Additionally, we have analysed how, given unequal anticipated effects across rich and poor countries, climate change can potentially reinforce both spatial inequalities and poverty trap dynamics. We have also described the potentially important effects of climate change on economic development through its indirect effects on the socio-political and institutional environment. First, climate change can alter the context within which institutional development takes place. Second, given its significant role in the likelihood and intensity of conflict, changing climatic conditions can also affect the socio-political stability of countries.

The evidence reviewed confirms distinct effects of climate shocks across rich and poor countries; the macro impacts of a changing climate will be felt more strongly in poorer, and especially in fragile, states. At the same time, it is in these same countries where the indirect effects of climate change become most relevant, potentially reinforcing institutional fragility and in turn vulnerability to climate shocks. Our analysis also highlights the need to take account of the interaction of climate change (risk) with other development trends (e.g. in the case of rapid urbanisation, increasing exposure to urban disasters, etc.) for the design of sound adaptation strategies and development plans.

Two main policy implications arise from our review. First, it has become evident how adaptation strategies to climate change are fundamental not just on their own right, but also as key elements of broader poverty-reduction and development strategies. Moreover, as climate shocks disproportionally affect the poor, addressing climate-related risks is also a

sound strategy in terms of inequality and poverty reduction. Second, given their interactions, both geographical and institutional factors need to be considered in the design and successful implementation of strategies for both poverty reduction and economic development. Not only do geographical factors affect institutional dynamics, but the institutional framework is also likely to condition the way geographical factors influence the evolution of poverty and economic development. Especially close attention is warranted for institutional development in geographically challenged countries (such as those with extreme and variable whether conditions, climate-associated epidemic diseases, etc.) where these interactions are expected to be strongest.

Finally, from our analysis many relevant questions for further research can be identified. Regarding direct effects of climate change on economic development, the main outstanding questions relate to identifying the precise causal mechanisms through which climate shocks impact on the economy. The policy implications of the current literature are mainly on the mitigation side – identifying negative economic impacts of climate vulnerability and shocks motivates efforts to minimise future climate change. However, in order to make policy-relevant conclusions for adaptation strategies future work should aim at better understanding of mechanisms and a move beyond reduced form estimation. Significant research gaps also remain regarding the potential indirect effects of climate change for economic development, via effects on the overall socio-political environment.

Our review suggests that there are a potentially important set of dynamic interactions and feedback loops between institutions, climate (impacts and vulnerability) and development, which to date have been understudied. However, we first need to improve our understanding of socio-political dynamics, where our knowledge still remains limited. In what refers to institutions, there is still a lot to learn about institutional change as well as its role in economic development (causal effects, context-specific institutional characteristics, feasibility of optimal institutions, etc.). Understanding the role of specific institutions in given contexts, and how institutions evolve and adapt in the face of major challenges, becomes even more relevant to understand the effects of major shocks such as those brought about by climate change.

Most empirical evidence on socio-institutional effects of a changing climate relates to (violent) conflict, but there are also potentially important mechanisms via other socio-cultural factors, institutional elements (including informal institutions, such as contract enforcement, trust and cooperation), political economy (incentives), accountability of political classes, the potential role of aid flows (including climate finance), many of which to date remain under-studied. In this way, it becomes critical, for instance, to understand how climate change will affect the political economy of governance (i.e. the domestic distribution of political power) and policy formation in challenged countries, or how institutional design should take account of climate risks, including concrete recommendations for development planning.

In sum, what seems clear from our analysis is that the effects of climate change, whether direct or indirect, seem of central relevance for sustainable economic development,

especially for poor countries, and in particular for those with fragile states. But our understanding of these effects remains limited. The topic clearly deserves further research.

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Notes:

[1] There is a long literature on the proximate determinants of cross-country differences in economic growth providing evidence on the role of capital accumulation (see for instance Barro, 1991; Young, 1995; Sala-i-Martin et al., 2004). Other variables commonly (and robustly) identified to be associated with economic growth include innovation and technology, measures of life expectancy, fertility, and economic specialisation, as well as geographical and institutional variables.

[2] Attention has variously focused on several potential deep-rooted determinants of development, including cultural differences (Ashraf and Galor, 2011), biogeographical factors (Diamond, 1997), geographical factors (Gallup et al., 1999, 2001; Easterly and Levine, 2003, among others), institutions (Acemoglu et al., 2001, 2002; Rodrik et al., 2004; Besley and Persson, 2011 and Acemoglu and Robinson, 2012), and most recently even genetic characteristics (Ashraf and Galor, 2013).

[3] The available evidence suggests that both geographical and institutional factors act as driving forces for economic development, with some authors arguing that geography produces most of its impact through its effect on institutional development (e.g. Acemoglu et al., 2001; Rodrik, 2004). Even controlling for (national level) institutions, however, geographical factors still seem to play a significant and direct role (see for example Sachs, 2003; Glaeser et al., 2004). The significant role of geography has also been analysed *within* countries (i.e., Nordhaus 2006, Dell et al. 2009).

[4] A sustained rate of economic growth has the potential to transform economies and lift millions out of chronic poverty. Of course, growth does not automatically translate into poverty reduction in the short-run, and for all members of society. Empirical estimates of the relationship between growth and poverty vary depending on the data used (Ravallion, 1995, Adams, 2004) and the composition and size of economic growth (Khan, 2009, Loayza and Raddatz, 2010 and Rose et al, 2013).

[5] Climate-resilient development is defined as ensuring that societies and different groups within them are able to cope with climate variability and to adapt to future climate change, trying to preserve development gains and to reduce the damages (USAID, 2014).

[6] Agglomeration in large urban centres, for instance, not only raises prices but also increases challenges related to transportation, pollution, social cohesion and the provision of adequate public services.

[7] The physiological response of human beings to temperature has been documented from heat studies in the lab (e.g. Wyndham, 1969). Such effects might be mitigated by a more widespread adoption of air-conditioning. As always, the ultimate impacts of climate will depend not just on the level of exposure but also on the sensitivity and adaptive capacity of affected regions and societies.

[8] While there might be possible benefits from higher temperatures in some regions due to short-term bio-productivity increases, negative effects of global warming on agriculture, due not just to higher temperatures but also to higher climatic fluctuations, appear to outweigh such benefits (Furuya and Koyama, 2005; Lobell and Field, 2007). For developing regions, the anticipated effects of climate change are expected to be particularly challenging from a socio-economic perspective (see e.g. Samson et al., 2011).

[9] Barrios et al. (2006) and Henderson et al. (2014) report a significant link between climate and urbanisation in Sub-Saharan Africa, which appears especially strong in arid regions. The mechanism is through reduced incomes (from agriculture) following periods of reduced moisture availability.

[10] Fankhauser and Tol (2005) have suggested, using model simulations, that the indirect (dynamic) impacts of climate change on growth, via lower capital accumulation, could be larger than direct levels effects on output.

[11] Several papers show that growth spurts and collapses are more common than simple 'convergence' or deterministic growth paths *a la* neoclassical growth theory (Rodrik 1999; Hausmann et al. 2005; Easterly 2006). Broadberry et al. (2013) argue that there is some threshold in terms of income and institutional development beyond which growth becomes more secure, but below which countries remain vulnerable to shocks.

[12] See Di John (2010) for a good review of the literature on "fragile" states.

[13] There are two prominent vies about on the role of institutions. First, based on Smith's (1776) idea of peace, easy taxes, and a tolerable administration of justice, as the requirements for economic development, Besley and Persson (2011) focus on the role of fiscal and legal capacity and political stability as the three pillars of

prosperity. Second, Acemoglu and Robinson (2012) explain how in the long run countries differ in their economic success because of their different institutions, either of extractive or inclusive nature. See Jennings (2013) for a more thorough review and comparison of these two approaches.

[14] Except to the extent that mitigation efforts and global climate negotiations might influence domestic politics. However, this is a distinct type of effect – likely operating on the political/ideological make-up of government, as opposed to affecting the fundamental quality of institutional and governance arrangements.

[15] In all these papers the aim is to identify a causal effect of institutions on economic development, typically by using instrumental variables estimations. While Mauro (1995) uses ethnolinguistic fragmentation to instrument for corruption, as proxy for institutional quality, the rest of the papers tend to rely on geographical variables as instruments for institutional variables. Hall and Jones (1999) rely on distance from the Equator, and Acemoglu et al. (2001) on settler mortality rates (in turn determined by disease environment given by geographic characteristics and climate). Engerman and Sokoloff (2000) argue that factor endowments (mainly in terms of soils, climate, mineral resources and availability of cheap and organised labour) determined inequalities in the structures of production and social organisations, which translated into persistent institutional arrangements perpetuating over time.

[16] Pande and Udry (2005) explain the limitations of cross-country approaches to analyse the effect of institutions on economic development. These limitations mainly relate to the coarseness of institutional measures and instruments, omitted variables, and heterogeneous treatment effects, all of which might lead to significant upward biases of the effect of institutions on long-run growth.

[17] As noted by several authors, today's developed countries did not need perfect institutions for industrialisation to take place; while some key reforms were essential many other good governance characteristics came along with the process of development (Chang, 2001; Grindle, 2004; and Rodrik 2008).

[18] The concept and measure of instability varies across studies. While some authors focus more on violent conflict, others consider broader measures of socio-political instability also taking into account social unrest and government stability or lack of it.

[19] In a reversal of circumstances, Pederson et al. (2014) report the 21st century drought in central Mongolia as being the hottest drought in the last 1,112 years.

[20] Blattman and Miguel (2010) provide a comprehensive review of war's (economic) causes and consequences, identifying several distinct approaches to modeling the origins of conflict.

[21] Weather shocks may increase food prices, typically leading to more frequent uprisings and riots. Depending on the circumstances and for specific locations, however, weather shocks might offset current food insecurity and help lower the risk of local conflict (Gartzke, 2012).

[22] Indeed, previous evidence supports the idea of decreased output and rural productivity lowering the opportunity cost of engaging in conflict and increasing the returns to violence. In a study of the Colombian civil conflict, Dube and Vargas (2013) present evidence that steep declines in coffee prices and increases in oil prices reduced workers' wages and increased their propensity to join armed groups. Likewise, Do and Iyer (2006) find a strong correlation between civil conflict and poverty and lower levels of human capital, which they consider is a proxy for opportunity costs.

[23] Clearly, in hotter climates periods of *higher* temperatures might be expected to create more difficult growing conditions.

[24] See Acemoglu and Robinson (2010, 2012), Besley and Persson (2011), Stiglitz (2012), Krugman (2012), and Piketty (2014). In Engerman and Sokoloff (1997, 2000), for instance, the argument rotates around inequality: "bad institutions" are the consequence of unequal structures of production and social organisations (as those implemented in Latin America after colonisation). Inequalities and bad institutions are in this sense two sides of the same coin, reinforcing each other and becoming persistent over time. Higher inequalities are generally associated with worse institutions (see Castells-Quintana and Royuela, 2014a), and are in fact considered as a relevant handicap for long-run economic growth (Clarke, 1995; Easterly, 2007; Castells-Quintana and Royuela, 2014b, among others)

[25] Ethnic favouritism has been identified as a factor also behind inequalities in many African and Asian countries, and represents a clear example of the reinforcing feedbacks between political and economic inequality, as well as of its negative outcomes (for instance, Fosu et al., 2006, found that the existence of ethnically biased interest groups is associated with sub-optimal provision of public goods). But Banerjee et al. (2011) bring some optimism showing how information about candidates in India can lead voters towards more conscious voting and away from relying solely on ethnicity. Increased audits and electoral accountability has led to similar results in Brazil (Ferraz and Finan, 2011).

[26] Other reports highlighting security risks of mass migrations include the *National Security and the Threat of Climate Change* report (CNA Corporation, 2007), the US Department of Defence 2010 *Quadrennial Defense Review*, and the *Climate and Social Stress: Implications for Security Analysis* (Steinbruner et al., 2013) report.