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Climate Change, Adaptation and Economic Growth

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Abstract

This paper explores the links between economic growth and the impacts of climate change. Inclusive, pro-poor growth is central to the development of low-income countries. There is also a broad consensus that growth and development are important to reduce vulnerability to climate change. Growth does not automatically reduce vulnerability, only the right kind of growth does. The paper aims to develop a better understanding of what the "right kind of growth" may be. We find that many growth policies, such as investment in skills and access to finance, indeed reduce vulnerability to climate change. However, climate change calls for some adjustments in growth policy. In particular, investment in infrastructure and efforts to stimulate entrepreneurship and competitive markets must take more of a risk management perspective and recognise climate risks.

Keywords: economic growth, development, adaptation

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1. Introduction

Inclusive, pro-poor growth is a central objective of development policy. As climate resilience emerges as an equally important development concern, it is worth asking to what extent existing growth policies are compatible with the adaptation needs of developing countries.

Low-income countries are much more vulnerable to climate change than richer nations (World Bank 2010a). The reason is a combination of three features: a higher physical exposure in many areas (e.g. proximity to temperature thresholds), a higher economic sensitivity to climate events (e.g. heavier reliance on agriculture) and a lower adaptive capacity (i.e. a lower ability to deal with climate stress).

The last two of these features are strongly influenced by economic growth. The ability to absorb climate stress, in particular, depends on factors that are highly correlated with economic growth, such as good institutions, strong health and sanitation systems, high levels of education and a well-developed financial sector (Tol and Yohe, 2007, Barr et al., 2010). Since growth and development address shortcomings in these variables, the implication is that growth must be important element of attempts to reduce vulnerability to climate change (Klein and Persson 2009, McGray et al. 2007).

However, economic growth does not only improve adaptive capacity. It also alters the sensitivity of developing countries to climate change. In some cases these effects will be positive, for example the diversification away from climate-sensitive agriculture. In others, the effect may be negative, for example if development is concentrated in high-risk areas like flood planes.

The net effect of economic growth on climate vulnerability is therefore uncertain. It is not the case that growth per se reduces vulnerability, as has sometimes been claimed (e.g., Schelling 1992, 1997). Only the right kind of growth will.

Moreover, climate change may itself alter the growth trajectory of a country, for example by reducing productivity (particularly in agriculture), destroying productive assets (during extreme events) or altering investment priorities (from productive investment toward adaptation).

It therefore remains a pertinent question how the growth strategies of developing countries may have to be adjusted to account for climate change. This paper reviews the available literature to develop a clearer understanding of what the "right kind of growth" might be.

The paper has five further sections. Section 2 recapitulates the theory of economic growth and identifies nine key features that are commonly associated with rapidly growing economies. Section 3 reviews the available evidence on how climate change may affect the pace of economic growth. Asks the reverse question, section 4 analyses how growth might affect (reduce or increase) the likely impacts of climate change. Section 5 turns to policy. Using the nine key features of growth identified earlier, it asks how growth policies will have to change to account for climate change. Section 6 concludes.

2. The determinants of growth

The growth and development literature has moved forward from the Washington Consensus of the 1990s, which stressed the advantages of leaving markets to their own devices (Williamson 1990). Most growth experts now see a clear role for public policy, which needs to ensure macroeconomic stability, create strong institutions that protect investors, open up to the world economy, encourage innovation and promote social cohesion, solidarity and political stability (see e.g., Acemoglu et al., 2001, Hausmann 2006, Rodrik et al., 2004, Winters 2004).

It is not just about institutions. Collier (2006) and Sachs (2003) argue that geography (both physical and human) also plays its part, not least in explaining the relatively poor performance of African countries.

The theory of growth and development thus suggests a number of features that are commonly associated with sustainable, private sector-led growth. Table 1 distinguishes nine such drivers of growth (inspired by DFID 2009 and World Bank 2005). There are a number of links and causalities among the nine (e.g. competition affects productivity), which one may wish to disentangle. However, for our purposes it is enough to note that all nine tend to be present in dynamic, fast-growing economies.

Climate change affects and is affected by these nine factors in many ways. In the following two sections, we explore the main channels through which this may happen.

Table 1: Nine essential factors of economic growth

Sufficient Capital

1. *Natural capital:* Sustainable management of natural resources like clean water, clean air, healthy ecosystems and mineral resources.

2. *Infrastructure:* A good-quality transport infrastructure (road, sea, air, rail), communication and information assimilation systems, municipal services and energy systems.

3. *Human capital:* Education and health outcomes in particular, which affect labour supply and productivity.

Sound business environment

4. *Macroeconomic stability:* Fiscal stability, price stability and currency stability, which are essential for business confidence.

5. *Institutional and regulatory framework:* The rule of law, low administrative barriers, absence of corruption, sound regulation and political stability.

Easy Access

6. Access to markets: Openness to regional and world markets, good access to the national economy, which increases opportunities in poor and remote areas.

7. Access to capital: Access to credit and risk capital, including for start ups, micro, small and medium-sized enterprises; access to foreign investment, which conveys new ideas and technologies.

High productivity

8. *Competitive markets:* Low barriers to entry and exit, a level playing field, and the absence of monopoly market power, encouraging innovation and adoption of best practice.

9. *Firm performance:* High productivity and resource efficiency in all sectors.

3. How climate change can affect economic growth

3.1 Evidence from simulation models

The standard neoclassical models of economic growth are those associated with Ramsey, Cass and Koopmans, in which growth is a function of saving, investment and capital accumulation. Unfortunately, they are not particularly well suited to the question of how growth in developing countries might be affected by climate change.

Important channels through which climate change can affect growth, such as population growth, migration patterns, productivity levels and capital depreciation are treated as exogenous in the basic model. This makes it difficult to model the impact of, for example, greater prevalence of vector-borne diseases on population growth, of reduced agricultural productivity, or of the accelerated depreciation of capital as a result of weather-related disasters.

Some attempts at quantification have nevertheless been made, typically using integrated assessment models, many of which have a neoclassical structure. However, they tend to focus on 'level' effects rather than growth rates. An exception is Fankhauser and Tol (2005). Using the DICE model (Nordhaus and Boyer, 2000), they found that the impact of climate change on output via reduced growth was larger than the direct 'levels' effect. But both effects were small, totalling less than a 0.2 percentage point reduction in the per capita global annual growth rate by 2205 and very much less in the short run. More research is needed using endogenous growth models and allowing for variations in the speed of convergence towards the global technological frontier.

Hallegate et al. (2007) focused specifically on climate variability. They argued that the long-term growth models commonly used in climate-change economics cannot capture the adverse effects of extreme weather events. They showed how, if the frequency of extreme events passes some threshold, economies can fall into a downward spiral in which they do not have the capacity to make good productive capacity lost. The implication is that adaptation needs to take account of the whole distribution of possible climate-change impacts, not just the mean. Impacts in the 'bad' tail of the probability distribution ought to be guarded against, because they can have devastating effects on growth over the longer term.

Climate change can affect output beyond the first-round impacts through general equilibrium adjustments that result in impacts through trade and factor markets, possibly subject to their own market imperfections. Most general equilibrium studies (e.g., Bosello et al., 2007, Eboli et al. 2010, World Bank 2010b) find that the economy-wide second-order effects generally increase the impact of climate change on welfare, although not necessarily in every economic sector and region. Bosello et al. (2007) concluded that direct costs are "a bad approximation of the general equilibrium welfare effects".

3.2 Empirical evidence

The results from simulation models, which project the future impacts of climate change, can be contrasted with the smaller body of empirical evidence about the historical impact of climate on growth.

There are very few studies that look at the link between climate (or average temperature) and economic output. The best evidence comes from Dell et al. (2008, 2009), who found that, in poor countries over the period 1950 to 2003, a 1°C rise in temperature in a given year tended to reduce economic growth in that year by 1.1 percentage points, and the effects on growth tended to be persistent. The estimated temperature effects over 10- or 15-year horizons were similar to the annual panel data estimate, with the implication that these effects represented changes to growth rates, not simply 'level' effects on income.

Unless offset by some other factor, such temperature effects would be sufficiently large to produce a much steeper relationship between temperature and income across countries than is actually seen in the data. The obvious offset is adaptation; their results implied that, eventually, adaptation offsets about half the negative effects of temperature variation on income. The authors found a similar (but weaker) relationship in state and local data.

There is more evidence about the impact of climate *variation* on growth. It suggests that extreme weather events can have a significant adverse effect on growth in the short run. Mechler (2004) for example reports that Hurricane Mitch, which hit Honduras in 1998, reduced the country's GDP growth rate by as much as five percentage points.

Raddatz (2009) found that natural disasters, especially climatic ones, have had a moderate but significant negative effect on real GDP per capita over the past four decades. He calculated that, at a conservative estimate, the macroeconomic cost of a climatic disaster

affecting at least half a per cent of a country's population reduced real GDP per capita by 0.6%.

Hallegatte and Ghil (2008) pointed out that economies may be able to respond more effectively to natural disasters if they have underutilised resources available. Hence, perhaps surprisingly, the costs of climate change and adaptation may be reduced by the presence of Keynesian unemployment or surplus labour. They argued that this is why some reviews of the costs of natural disasters have not found them to be particularly high (see, for example, Hochrainer 2009).

Landon-Lane et al (2009) found that at the time of the great Dust Bowl in the USA in the 1930s, climatic stress hit the banking system, impairing financial intermediation and recovery for a prolonged period. Thus climate-related disasters can have long echoes through the financial system. Lis and Nickel (2009) showed how natural disasters tend to have an adverse impact on government budgets.

Hornbeck (2009) drew attention to another aspect of the great Dust Bowl: adjustment happened primarily through migration out of the affected regions, not through inward capital flows, changes in agricultural practices or a movement of resources into industry. Migration can help adaptation to climatic change and extreme weather events. However "the fewer choices people have about moving, the less likely it is that the outcomes of that movement will be positive" (Barnett and Webber 2010).

4. How growth can cushion climate-change impacts

Vulnerability to climate change is a function of two socio-economic variables (see e.g. Barr et al. 2010): (i) the *sensitivity* of a country to climate events, which in turn determines the physical impact of a given climate exposure, and (ii) a country's *adaptive capacity*, that is, its ability to deal with this impact.

Economic growth almost always increases the adaptive capacity of people. A society's ability to cope with climate events is highly correlated with basic development indicators such as income, education and institutional quality.

However, economic growth can either increase or decrease the sensitivity of a country to climate change. Diversification away from agriculture into manufacturing, for example, is

likely to reduce the severity of climate change impacts. In contrast, agricultural expansion that increases reliance on scarce water resources could increase potential impacts, as could economic development in hazard zones (e.g., flood plains or low-lying coastlines).

The net impact of these effects is unclear a priori. However, the empirical evidence suggests that the positive effects tend to dominate. Raddatz (2009) concluded that climate-related disasters had a higher GDP impact in low-income countries than in middle-income countries, which were in turn more affected than high-income ones. Dell et al. (2008, 2009) found that higher temperatures reduced economic growth rates only in poor countries, and not in rich ones. Noy (2009) found that certain development indicators were associated with a lower GDP loss from a given climate-related disaster, including GDP per capita, literacy, strong institutions, trade openness and depth of financial markets.

There is further evidence from case studies that poverty tends to exacerbate the costs of climate change (see e.g., O'Brien et al. 2008). Benson and Clay (1998) suggested a U-shaped relationship between development and vulnerability to climate change: the economic impact of climate-related shocks such as drought was higher for economies that had moved from a 'simple stage' of water-intensive agriculture and subsistence sector to an 'intermediate stage,' characterised by labour-intensive low-technology manufacturing, but vulnerability was lower where economies had become more diversified and developed.

5. Revising Growth Policy

Based on the evidence of the previous sections, we next ask how economic growth policies may have to be reviewed in light of climate change. We use the nine key drivers of growth identified in Table 1 to do so.

5.1 Natural capital

Traditional growth policies tend to neglect the environmental impacts of growth, but it is key both for adaptation and sustainable development. Climate change makes safeguards for ecosystems an even more important policy goal.

Climate change will compound existing pressures on ecosystems, speeding up their destruction and the loss of biological diversity. Removing baseline pressure by managing natural resources sustainably would strengthen their resilience and increase their ability to adapt naturally to climate change (Parry et al. 2007, see also Patt et al. 2010b).

Healthy ecosystems can themselves contribute to adaptation (e.g. coastal protection through mangrove forests or wetland zones). Hornbeck (2009), analysing the 1930s Dust Bowls, showed how environmental degradation, in this case over-farming, can have significant economic effects and trigger deep structural change (many farmers were forced off the land and left unemployed).

5.2 Infrastructure

The need for infrastructure investment over the coming decades is enormous. Climate change does not alter this need but may increase its costs. Climate change may also affect where infrastructure is built and how it is designed. There may be a need for additional infrastructure, dedicated to climate protection, such as sea defences and flood protection.

Making infrastructure resilient to climate change is an important and early adaptation challenge. This is not cheap: infrastructure adaptation tends to dominate adaptation cost estimates (Fankhauser 2010). It also requires sophisticated decision-making, given how little we know about future climate effects at the regional level (Ranger et al. 2010). However, starting this process is important. Infrastructure assets are long-lived and have the potential to lock in development patterns for a long time (World Bank 2010b).

5.3 Human capital

Two areas of human capital are of particular concern in dealing with a changing climate – education and health. Both are key to improving resilience to climate shocks as well as priority development goals. However, additional stress from global warming will also make it more difficult to achieve existing development targets for health and education.

More and better education can help people to understand, cope with and respond to changes in climatic conditions (Toya and Skidmore 2007). This finding is particularly strong for the education of women (Wheeler et al. 2010).

Climate-specific know-how and information are a powerful factor in improving agricultural performance. Trained farmers with access to accurate information make better management decisions (for example choosing crop varieties that are less dependent on volatile rainfall; Di Falco et al. 2010) and are more likely to use insurance as a risk mitigation tool (Patt et al. 2010a).

Conversely, climate shocks may affect human capital accumulation. Evidence from rural

India shows that those born during floods in the 1970s were 19% less likely to have attended primary school (UNDP 2007). Crespo Cuaresma (2009) found that, as the risk of natural disasters increases, the accumulation of human capital (measured as secondary school enrolment rates) falls.

Worsening health outcomes have a similarly detrimental effect on human capital (Parry et al. 2007). The occurrence of tropical diseases such as malaria not only limits countries' ability to develop but also their capacity to deal with climate shocks.

5.4 Macroeconomic stability

A higher probability of extreme events may make fiscal sustainability both more important and more difficult to achieve (Lis and Nickel 2009; Mechler et al. 2006). Government budgets may come under pressure if more funding is required for emergency services and reconstruction. There may also need to be an expansion of the availability of international capital to counter climate shocks.

Fiscal pressure may be compounded by a temporary fall in revenues in the aftermath of a disaster and by the risk of moral hazard if private actors rely on public emergency coverage (Heipertz and Nickel 2008).

Macroeconomic effects will depend on the economic cycle. Hallegatte and Ghil (2008) show that some output flexibility may be good in the face of a negative climate shock. In a world with underemployed factors of production, such resources can be deployed to assist reconstruction after a climate shock, thus limiting the loss in output. However, if the shock hits the economy in a boom, when there is little spare capacity to rebuild, output may fall over the medium term. The policy implication clearly cannot be to maintain slack in the economy. A more likely remedy would be access to foreign labour and capital resources that can be deployed in periods of full capacity utilisation.

5.5 The institutional and regulatory framework

Climate change strengthens the case for institutional policies, which have both growth and adaptation benefits. It is possible that the two objectives require different types of capacity or institutions (e.g. related to the business environment in one case and emergency services in the other). However, it is likely that strong generic institutions will build up and evolve endogenously to tackle problems as they arise.

The empirical literature finds that better institutions result in a faster, more efficient response to climate shocks and that the shock itself does less damage to output (Noy 2009; Hallegatte and Ghil 2008). Dell at al (2008, 2009) suggest that support for institutional reform directly helps to increase adaptability within the economy, and indirectly increases adaptability by increasing income levels (thus reducing a country's vulnerability to climate change and shocks).

5.6 Access to markets

Trade openness is associated with faster growth, but from an adaptation point of view there are both positives and negatives associated with reliance on international markets.

There is some evidence that openness to trade makes economies more resilient to climate shocks by making producers less reliant on domestic markets and consumers less reliant on domestic production (Noy, 2009; Carter et al. 2007; UNDP 2007).

However, openness also makes it easier for local climate effects to spread internationally. The UK Government Office for Science (2011) concluded that the consequences for the UK of climate change occurring in other parts of the world could be as important as the direct domestic effects.

Moreover, if trade engenders greater specialisation, that may expose countries to additional risks, if the specialisation is in climate-sensitive areas or if countries become reliant on a vulnerable trade infrastructure. As a non-climate example, Kenya's flower industry lost heavily when a volcanic ash cloud grounded freight flights to Europe in 2010.[1] Greater openness may also drive workers into less productive and more vulnerable informal sectors, as has happened in Africa and Latin America according to McMillan and Rodrik (2011).

Gassebner et al (2010) find that natural disasters have a negative impact on trade flows in the short run, reducing both imports and exports, which suggests that both effects may operate and the type of shock is crucial in determining the outcome.

[1] http://www.csmonitor.com/World/2010/0419/How-the-Iceland-volcano-ash-cloud-is-crippling-Kenya-s-flower-industry

5.7 Access to capital

Climate change reinforces the need for better access to capital. At the macro level, access to funds for reconstruction is likely to become more important, while micro-finance generally targets those most vulnerable to climate change. However, the products offered may need to change, e.g. by expanding opportunities to insure against climate shocks.

Openness to capital markets has been shown to increase climate resilience, through inflows for reconstruction. This could replace the need for domestic buffer stock saving in case re-building is necessary (see discussion on macroeconomic stability above). However, over-reliance on inflows prior to the shock can result in the opposite effect, as capital flight after the shock worsens the country's capital account position (Noy, 2009).

A strong domestic financial system and access to domestic capital are equally important. Resilience to climate shocks will require domestic financial firms to be fully diversified, in particular not overly reliant on the vulnerable agricultural sector. Hornbeck's (2009) study of the Dust Bowl shows how over-specialisation of the financial system makes it vulnerable to climate shocks and how this can have both level and growth rate effects on income.

Agrawala and Carraro (2010) argue that micro-finance may be an effective way to encourage resilience and adaptation. Many micro-finance initiatives are implicitly tackling climate change already, e.g. through investment in crop diversification and support for disaster relief.

At the same time, many of the projects financed by micro-finance institutions are vulnerable to climate change. Agrawala and Carraro estimate that 70% of the micro-portfolio in Bangladesh could be affected by climate change, and usually negatively so.

5.8 Competitive markets

The conventional wisdom is that free markets are more shock-resilient and induce greater adaptation in agents, but there is little empirical evidence.

Competitive markets are thought to be more flexible and able to react quickly to changing circumstances. This happens through a combination of market entry and exit and the response of existing firms to market signals. Flexibility is an important aspect of good adaptation, given widespread uncertainty about climate change impacts and the likely increase in climate variability.

Competitive markets may also facilitate diversification away from vulnerable sectors like agriculture (Carter et al. 2007). This can have both growth and adaptation benefits. Bangladesh, for example, has managed to reduce the impact of climate shocks on its economy by diversifying away from agriculture into the garment industry (Benson and Clay 1998, 2004).

Despite this, it is not clear that competitive markets are always beneficial. Hausmann and Rodrik (2006) have argued that the market may fail to provide all the necessary capabilities to move into new sectors, and as a result government intervention may be necessary.

5.9 Firm performance

Whilst economic growth is supported by productivity improvements in all sectors, the main focus for climate change is on agriculture. There is a growing need to improve agricultural productivity, both to meet growing food demand and to deal with the consequences of climate change. However, finding the right balance between yield maximisation and risk minimisation is not easy.

Dealing with climate events effectively is key to increase agricultural productivity in low-income countries (see e.g. di Falco et al 2010). Increased agricultural productivity can in turn help to ease potential food shortages and pressure on food prices, whether they are brought about by climatic factors, increased food demand or competition for land from biofuels.

However, there is a risk that some productivity measures could increase vulnerability to climate change, for example if they entail increased reliance on scarce water resources. Farmers will have to optimise their expected return, bearing in mind different possible climate outcomes, but they will also want to reduce the risk of a failed harvest (Dercon 2002).

6. Conclusions

There are strong overlaps between growth policy and adaptation policy. Climate change accentuates many of the market and public policy failures that motivate growth policies and hence increases the general case for these measures. The exact nature of the climate change / growth link requires further analytical scrutiny, but some lessons can already be drawn.

First, it is clear that climate events have the potential to affect growth trajectories. Higher temperatures and more climate extremes tend to be associated with lower rates of growth, at

least in developing countries. Factors such as fiscal stability and human capital accumulation, which are associated with fast growth, can be affected by extreme weather events. However, most of what we know about the economic impact of climate change concerns the *level* of economic activity, rather than the *rate of growth*.

Second, there is an unambiguous and positive link between economic growth and adaptive capacity. A country's capacity to deal with climate events is associated with factors such as institutional quality, educational attainment, financial intermediation and income per capita that tend to improve as economies growth. We do not yet fully understand how these factors work together – for example, whether they are complements or substitutes (that is, whether better performance in one area can make up for weaknesses in another) or how quickly decreasing returns kick in (that is, when the effect of better development performance begins to level off). The answer to these questions will have implications for how policy support should be prioritised.

However, as a rule of thumb, improvements in development indicators associated with adaptive capacity, through growth and other policies, are an effective and unequivocal way of reducing vulnerability to climate change. For many, this is therefore the first priority of adaptation investment, alongside the climate-proofing of long-lived investments (Fankhauser and Burton 2011; World Bank 2010b).

Third, the effect of economic growth on a country's sensitivity to climate change is ambiguous. This is therefore an area that requires a systematic approach to risk management. Growth policies should begin to assess climate risks as a matter of course. Efforts to increase agricultural productivity or develop coastal zones, for example, should not come at the expense of higher susceptibility to climate shocks. The design of new infrastructure, crucial for growth and development, will also have to be amended to make these structures fit for climate change.

Systematic risk assessments may identify win-win opportunities as well as risks. Maintaining a healthy natural capital stock, for instance, is key for both sustainable growth and an increase in the adaptive capacity of ecosystems.

Fourth, climate change may reinforce the need for collective action. Modern growth theory emphasises (again) the role of public policy in overcoming market failures and investment barriers (Acemoglu et al., 2001, Hausmann 2006, Rodrik et al., 2004). Climate change

highlights and amplifies the importance of a range of market imperfections (and policy failures) that warrant more emphasis on the promotion of effective collective action, including by the state.

There is no automatic link between climate change vulnerability and growth. But if the above lessons can be incorporated into growth policies, they can make an important contribution to reducing vulnerability to climate change.

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