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Climate Change, Growth and Infrastructure Investment: The Case of Mozambique

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Abstract

Climate change may damage road infrastructure, to the potential detriment of economic growth, particularly in developing countries. To quantitatively assess climate change's consequences, we incorporate a climate–infrastructure model based on stressor–response relationships directly into a recursive dynamic economy-wide model to estimate and compare road damages with other climate change impact channels. We apply this framework to Mozambique and simulate four future climate scenarios. Our results indicate that climate change through 2050 is likely to place a drag on economic growth and development prospects. The economic implications of climate change appear to become more pronounced from about 2030. Nevertheless, the implications are not so strong as to drastically diminish development prospects. Our findings suggest that impact assessments should include damages to long-run assets, such as road infrastructure, imposed by climate change.

1. Introduction

Economic growth is widely held to depend on the quantity, quality, and orientation of a country's backbone infrastructure. Inadequate infrastructure in many developing countries therefore presents a serious constraint to economic development. In order to address this constraint, governments in developing countries often assign a large share of their budget to public infrastructure spending, with particular emphasis on roads. Moreover, while foreign aid often finances extensions to low-income countries' road networks, recipient governments frequently cover the cost of maintaining infrastructure after it is installed.

In this paper, we consider the interactions between climate change, growth, and investment in economic infrastructure, with an application to Mozambique. We are motivated by two observations. First, much of Mozambique's installed infrastructure is vulnerable to climate change, with the most likely threats being shifts in the frequency, severity, and character of extreme weather events. Secondly, while some manifestations of climate change are already observable in Mozambique, deviations from conditions currently regarded as normal are likely to become far more profound with time. The potential risks to economic infrastructure posed by climate change are likely to be much larger in 2050 than they are today. A simple but pertinent observation is that, in many developing countries, it is highly likely that the bulk of economic infrastructure

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that will exist in 2050 does not exist today. As a result, the vulnerability of future infrastructure is, to a considerable degree, a matter of choice.

The remainder of this article is structured as follows. Section 2 focuses on road infrastructure, which is typically the largest component of public infrastructure investment. It reviews the literature on roads, economic growth, and climate change. Section 3 briefly describes our case country, Mozambique, and presents the four climate change projections selected for our analysis. Section 4 describes the dynamic computable general equilibrium model (DCGE) developed for this analysis; how the road model developed by Chinowsky and Arndt (2012) is linked to the DCGE model; and presents estimates of the economy-wide cost of climate change in Mozambique. Finally, section 5 summarizes and concludes.

2. Roads and Growth

Numerous studies confirm the importance of road infrastructure for economic growth. Fernald (1999), for example, examined data for the USA for the period 1953–1989 and concluded that road investments had a significant causal impact on productivity growth during 1953–1973—the period when the interstate highway system was constructed. The author estimated that public investment, principally in roads, “contributed about one percentage point to total factor productivity growth” (p. 620). To achieve this gain, net road investment exceeded “a quarter of the value of net nonresidential private investment” (p. 619). Public road investments therefore contributed to the USA’s strong economic performance during the 1950s and 1960s. After 1973, Fernald asserted that the marginal product of road investments declined (i.e. a second interstate highway system is less beneficial than the first).

Developing countries, particularly in Africa, are unlikely, in the foreseeable future, to face a declining marginal product of road infrastructure investment because of excess supply since road stocks in these countries are low by almost any measure. Of course, the marginal (and average) product of infrastructure investment can be low for other reasons. Governments can, for example, waste resources constructing poor quality or unnecessary infrastructure. Nevertheless, the empirical evidence is generally favorable to the proposition that public road investments generate reasonable returns. For example, Esfahani and Ramirez (2003) used cross-country panel regressions and found that infrastructure services’ contribution to gross domestic product (GDP) is substantial and exceeds the cost of their provision (p. 443). Similarly, Calderón and Servén (2004) found that growth in Latin America is positively related to infrastructure stocks and that income inequality declines with higher infrastructure quantity and quality. More recently, these authors applied the same techniques to Africa (Calderón and Servén 2008) and reached similar conclusions.

A litany of methodological problems haunts the cross-country regression literature (see, for example, Roodman, 2009). However, country-level studies are also generally positive. In a study of Nepal, Jacoby (2000) found that “providing extensive road access to markets would confer substantial benefits on average, much of these going to poor households” (p. 713). Also for Nepal, Dillon et al. (2011) concluded that rural roads are one of the most productive public expenditures. In Portugal, Pereira and Andraz (2005) found positive returns to infrastructure both with respect to growth and the public purse. For Latin America, Rioja (2003) found a substantial growth drag as a result of degraded or inefficient infrastructure. Fan and coauthors conducted detailed studies to estimate the returns to public investment in China, India, and Uganda (Fan et al., 2004; Fan and Chan-Kang, 2008; Fan and Hazell, 2001; Fan and Zhang, 2008). They consistently found positive returns to road investments, particularly rural roads. These and other findings led Ndulu (2006) to call for a "big push in promoting infrastructure" in Africa in order to overcome underdevelopment and sustain economic growth.

Both theory and evidence therefore suggests that infrastructure investments are important determinants of economic growth and poverty reduction. In most developing countries, these investments represent commensurately large shares of public budgets and total investment. If the stock of public capital in general and the road stock in particular is material to growth and poverty reduction, then the rate of depreciation of that stock is also material. Climate change may contribute to more rapid deterioration of road stocks owing to higher temperatures, more intense precipitation, and more frequent or more intense flooding (Chinowsky and Arndt, 2012).

3. Mozambique

Economic Characteristics

Mozambique has experienced both a struggle for independence and a subsequent civil war. However, since the mid-1990s the country's development trends have improved considerably. The economy has grown rapidly (even if the large-scale capital-intensive "mega-project" investments are excluded and despite a recent downward adjustment to past agricultural growth (see Arndt et al., 2011a)). Improved economic conditions have been felt by most segments of the population, albeit not in equal measure. The national poverty headcount fell from 69 to 55% during 1997–2009, and infant mortality rates fell from 149 to less than 100 per 1000 births during 1996–2008. Education levels have also improved dramatically.

With agriculture accounting for about a quarter of GDP and three-quarters of employment, improved rural infrastructure is often viewed as critical to future economic growth and poverty reduction. Poor infrastructure, large distances, and associated weak market development generate large differences between farm-gate and urban prices for agricultural products. Tarp et al. (2002) showed that reducing these marketing margins results in strong poverty reductions, particularly if agricultural productivity rises simultaneously. Recent work showed that high marketing margins, slow agricultural growth, and external terms of trade shocks explain the recent slowdown in poverty reduction despite rapid national economic growth over the period 2002/03 to 2008/09 (Arndt et al., 2011a).

Climate Change Scenarios

The impact of climate change on Mozambique is explored using four scenarios based on different pairings of general circulation models (GCMs) and global emission scenarios. These four scenarios were selected in an attempt to represent the possible variability in future climate moisture within Mozambique. The NCAR-CCSM sres_a1b represents a "global wet" scenario and CSIRO-MK3.0 sres_a2 represents a "global dry" scenario. While these GCM/emission scenario pairings represent the wettest and driest scenarios globally, they are not necessarily the wettest or driest for Mozambique. Therefore, the wettest and driest GCM/emission scenarios for Mozambique are also included. Specifically, the UKMO-HADGEM1 sres_a1b is the "Mozambique dry" scenario, and IPSL-CM4 sres_a2 is the "Mozambique wet" scenario.

Table 1 shows that all sub-national regions in Mozambique are expected to experience a 1–2 degC increase in temperature by 2050. This increase occurs under both wet and dry

Table 1. Climate Changes in Mozambique by 2050

	Global dry CSIRO	*Global wet NCAR*	*Moz. dry UKMO*	*Moz. wet IPSL*
Temperature change (Celsius)				
North region	1.23	1.89	1.37	1.47
Center region	1.40	1.81	1.78	1.49
South region	1.51	1.58	1.66	1.36
Precipitation change (%)				
North region	3.50	1.94	–22.46	18.23
Center region	–6.96	–2.12	–27.19	6.36
South region	–11.87	1.50	–21.74	15.60

Source: Own calculations using GCM results (Commonwealth Scientific and Industrial Research Organisation (CSIRO), National Center for Atmospheric Research (NCAR), United Kingdom Meteorological Office (UKMO), and Institut Pierre Simon Laplace (IPSL)).

scenarios, and reflects the general consensus that temperatures will rise as a result of climate change (Intergovernmental Panel on Climate Change (IPCC), 2007). Greater variation in average precipitation changes exists in our four scenarios reflecting a lack of consensus among GCMs over precipitation projections at localized scales (IPCC, 2007). Differences in precipitation patterns across projections are even more pronounced at daily and monthly time scales. Overall, the four GCMs suggest that Mozambique's climate will become hotter and more variable as a result of climate change.

We use historical monthly climate data (0.5° × 0.5°) from the Climate Research Unit for 1951–2000 to produce a baseline "no climate change" scenario for each sub-national region. Our baseline scenario assumes that future weather patterns will retain the characteristics of historical climate variability. It should be noted that the purpose of the baseline scenario is not to predict future weather patterns, but to provide a counterfactual for the climate change scenarios. In order to generate future climates, we overlay a 10-year moving average of the monthly deviations in temperature and precipitation predicted by the GCMs onto the baseline scenario. For example, if the 10-year moving average for rainfall around January 2031 increases by 10% for a given GCM, then the historical realizations for precipitation in January 1981 are multiplied by 1.1. This procedure produces four "synthetic" climate projections containing both current climate variability (i.e. the historical baseline) and future climate changes.

Climate change is expected to lead to greater rainfall intensity. Note that, when the GCMs predict greater rainfall, the procedure described above both increases the volume of rainfall and the variance of the precipitation series. This can lead to a greatly increased probability of severe flooding events. Consider an analysis of flood return periods for two of the selected GCMs for the North of Mozambique taken from Strzepek et al. (2010). The results are presented in Figure 1 in the form of flood return periods with the maximum return period set at a 100 year flood. Results vary strongly by GCM. The UKMO (Mozambique dry) scenario results in a small increase in the average flood return period but no appreciable increase in the probability of extreme flooding relative to the baseline. For the CSIRO scenario (global dry), in contrast, the probability of extreme flooding events rises dramatically. Major flooding events have substantial economic implications (Christie and Hanlon, 2001; Noy, 2009; Chinowsky and Arndt, 2012).

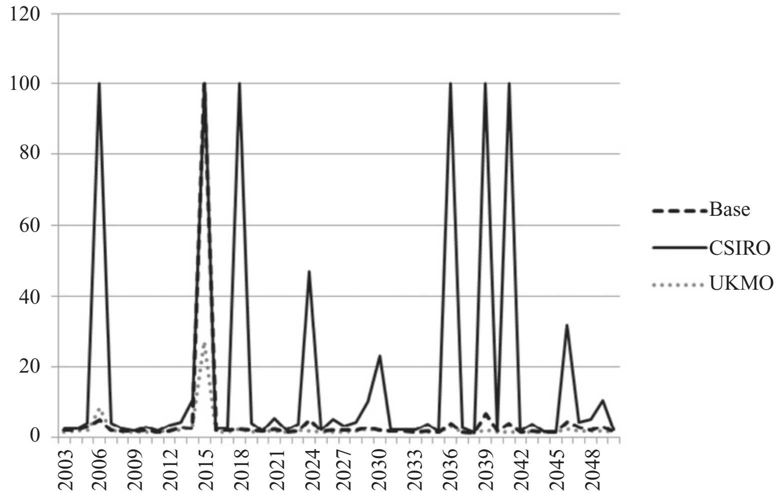

Figure 1. Simulated Flood Event Return Periods for Northern Mozambique

Source: Strzepek et al. (2010).

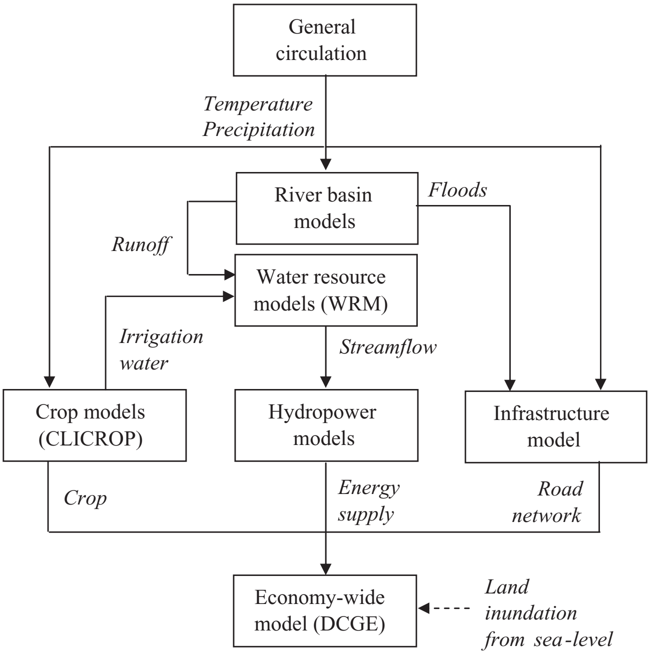

Figure 2. Integrated Modeling Framework

4. Economy-wide Implications of Climate Change with Focus on Road Infrastructure

Figure 2 illustrates the integrated modeling framework employed to consider the impacts of climate change and alternative adaptation options on an economy-wide basis. Arndt et al. (2011b) and Strzepek et al. (2010) described the river basin, water resources, crop, and hydropower models employed to analyze sector impacts. We first introduce the recursive dynamic computable general equilibrium (DCGE) model employed in the framework shown in Figure 2 to estimate economy-wide impacts. Next, we consider climate change impacts with particular focus on the methods for incorporating the road model (CLIROAD) of Chinowsky and Arndt (2012) into the DCGE model.

Recursive Dynamic CGE Model

Our DCGE model belongs to the structural neoclassical class of CGE models (see Dervis et al., 1982). These models are well-suited to analyzing climate change. First, they simulate the functioning of a market economy, including markets for labor, capital and commodities, and can therefore evaluate how changing economic conditions are mediated via prices and markets. Secondly, these models ensure that all economy-wide constraints are respected, which is crucial for long run climate change projections. Finally, CGE models contain detailed sector breakdowns and provide a "simulation laboratory" for quantitatively examining how the individual impact channels of climate change influence the performance and structure of the whole economy.

Economic decision-making in the DCGE model is the outcome of decentralized optimization by producers and consumers within a coherent economy-wide framework. A variety of substitution mechanisms occur in response to variations in relative prices, including substitution between factors, between imports and domestic goods, and between exports and domestic sales. The Mozambique model contains 56 activities or sectors, including electricity generation, transport services, and 24 agricultural subsectors (see McCool et al., 2009). Five factors of production are identified: three types of labor (unskilled, semi-skilled and skilled), agricultural land and capital. The agricultural activities and land are distributed across the three subnational regions (North, Center, and South). This sector and regional detail captures Mozambique's economic structure and influences model results.

The long timeframe over which climate change will unfold implies that dynamic processes are important. The recursive dynamic specification of our CGE model allows it to capture annual changes in the rate of physical and human capital accumulation and technical change. So, for example, if climate change reduces agricultural or hydropower production in a given year, it also reduces income and hence savings. This reduction in savings displaces investment and lowers production potential. Similarly, higher road maintenance costs imply less infrastructure investment and shorter road networks both now and in the future. Extreme events, such as flooding, also destroy infrastructure with lasting effects. Generally, even small differences in accumulation can cause large differences in economic outcomes over long time periods. The DCGE model is well suited to capture these path dependent effects.

Modeling Climate Change Impacts on Roads and Other Sectors

As shown in Figure 2, climate change affects economic growth and welfare in the DCGE model via four principal mechanisms. First, productivity changes in rain-fed agriculture are taken from detailed crop models and the DCGE then determines how much resources should be devoted to each crop given their profitability relative to other activities (i.e. "autonomous adaptation"). Secondly, the DCGE model directly incorporates fluctuations in hydropower production based on a river flow model (see Arndt et al., 2011b). Thirdly, the DCGE model incorporates the effects of sea level rise by reducing the total amount of cultivable land in each region by the land inundation estimates from the "DIVA" model (i.e. dynamic and interactive vulnerability assessment—see Strzepek et al. (2010) for details on the application to Mozambique).

Finally, the road model (CLIROAD) presented in Chinowsky and Arndt (2012) is incorporated directly into the recursive DCGE model. CLIROAD interacts with the DCGE model through two mechanisms. First, the budget allocated to roads (investment and maintenance) grows along with government spending on commodities. Second, road extension in any given time period is assumed to influence the underlying rate of Hicks-neutral factor productivity (HFP) growth. Specifically, the following formula is employed:

$$HFPGr_t^i = HFPGr_t^{base} \times \left(\frac{road_t^i}{road_t^{base}} \right)^{1/2}$$

where *HFPGr* refers to the TFP growth rate, *i* refers to the climate scenario, *base* is the no climate change climate, *road* refers to the overall extent of roadstock in kilometers, and *t* refers to the time period. Note that the linkages between CLIROAD and the DCGE imply feedback. If climate change generates a more severe flooding event than under the baseline climate scenario, the growth rate is slowed for two reasons. First, the flooding event reduces road extent which reduces HFP growth via the formula above. Second, through time, the reduced rate of economic growth caused by the reduction in HFP growth implies a reduced rate in the growth of the road network owing to a reduction in the rate of growth of government investment in infrastructure, which also implies lower HFP growth. Other economic impacts from climate change which reduce the economic growth rate, such as broad based reductions in crop yields, will also eventually reduce the rate of HFP growth through the infrastructure investment channel.

The rate of total factor productivity (TFP) growth is higher than the growth in HFP because of the assumption of labor force upgrading (biased technical change in favor of labor and particularly skilled labor). The rate of HFP growth in the baseline is 0.8% per year in agriculture and 1.2% per year in non-agriculture.

These assumptions imply that if, in scenario *i*, the road network extent falls to 90% of the baseline in period *t*, HFP growth is reduced by about 5% in that period. Recall that Fernald (1999) estimated that road investment in the USA added a full percentage point to US TFP growth over the period 1953–73, which means that road investment contributed nearly two thirds of US TFP growth over the period. The benefit–cost ratios estimated by Fan and his coauthors also imply similarly large TFP gains to investments in roads in a number of developing country contexts (Fan et al., 2004; Fan and Chan-Kang, 2008; Fan and Hazell, 2001; Fan and Zhang, 2008). As noted, these relationships do not hold in all places at all times. Poorly implemented investments are unlikely to yield high returns. Eventually, road investments, like all other investments, suffer diminishing returns. Nevertheless, relative to these benchmarks, the formulations described above would appear to be a conservative estimation of the economic implications of road infrastructure damage caused by climate change.

Results: Linked CLIROAD DCGE Impacts on Infrastructure

The sets of assumptions discussed in the preceding paragraphs, including the other impact channels (crop models, hydropower models, and reduction in available cropping area because of sea level rise), were incorporated into the linked CLIROAD and

DCGE model. The implications for road extent are depicted in Tables 2 and 3. The Tables also include results from two adaptation scenarios. In the first, labeled "design standard evolution," paved road design standards are changed in accordance with a 10-year moving average of climate temperature and precipitation outcomes. In the second, new roads and rehabilitated roads are upgraded (at a cost) in order to increase robustness of the road network in the event of flooding (Chinowsky and Arndt, 2012).

From Table 2, one can see that the basic conclusions with respect to adaptation pertain as in the standalone version of CLIROAD (Chinowsky and Arndt, 2012). Specifically, design standard evolution supplies benefits in all scenarios; however, the costs of broad based flood investments outweigh the benefits. Table 3 compares results between the standalone version of CLIROAD and the linked DCGE versions of CLIROAD. In order to facilitate comparison, the road infrastructure budget applied to CLIROAD in the BASE run of the standalone version is exactly the budget developed in the BASE scenario of the DCGE model. As a result, in the BASE scenario, CLIROAD produces exactly the same results in standalone and DCGE modes.

As expected, the feedback effects derived from linking the models accentuate climate change impacts. The DCGE version produces lower final year total road infrastructure for all four climate change scenarios. The differential between the standalone version and the DCGE version is particularly strong in the CSIRO climate scenario, which produced the strongest climate impacts in standalone. The linked CLIROAD and DCGE model projects a final road extent in 2050 under the CSIRO climate that is only 85% of the BASE level.

Results: Economy-wide Impacts of Climate Change

Table 4 illustrates the implications of climate change for the growth rate of real absorption (a good proxy for economy-wide welfare). These implications are uniformly negative across scenarios and appear to be potentially significant for Mozambique. The Table illustrates baseline growth rates and then deviations from baseline by climate change scenario for the full simulation period (2003–2050) and by decade. Climate change impacts and then adaptations are introduced sequentially and cumulatively. First, impacts from yield changes and sea level rise (SLR) are imposed. Second, impacts from transport (CLIROAD) and hydropower generation are added. Out to 2050, the economic growth implications of climate change for sea level rise are small and for hydropower generation very small. Crop yields and transport infrastructure dominate the analysis. Hence, discussion focuses on these elements.

In the CSIRO (global dry) scenario, the annual growth rate of per capita absorption falls by about 0.11 percentage points as a result of climate change when all effects are accounted for (see the panel labeled "Transport & Hydro") with the largest impact coming through the transport channel. Design evolution results in more favorable absorption outcomes in three out of the four cases and is able to recoup 14% of the growth rate losses in NCAR scenario (though this adaptation slightly worsens outcomes in the IPSL scenario). Broad-based flood investments worsen overall outcomes as in the standalone CLIROAD model. It is noteworthy that climate change impacts tend to worsen with time in all climate scenarios. Finally, transport effects are large in the CSIRO and NCAR scenarios but smaller in UKMO and IPSL. In the latter, yield effects tend to dominate.

Figure 3 illustrates the loss in real absorption over the period. In all scenarios, more substantial losses begin to accumulate around 2030. In the worst case scenario (CSIRO), the net present value (in 2003) of the losses over the period amount to

Table 2. Deviation in Road Network Length in 2050 from Baseline (%) Using CLIROAD Linked to the DCGE

	North	*Center*	*South*	*Urban*	*Primary*	*Secondary*	*Tertiary*	*Paved*	*Unpaved*	*Totals*
	Without adaptation (%)									
BASE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CSIRO	–16.0	–15.2	–13.6	–12.1	–14.1	–16.2	–13.9	–15.1	–14.6	–14.8
NCAR	–8.3	–7.4	–10.1	–6.4	–8.4	–10.9	–5.9	–10.9	–6.8	–8.4
UKMO	–4.7	–4.3	–6.7	–3.7	–5.2	–7.1	–3.0	–7.2	–3.7	–5.1
IPSL	–5.2	–5.0	–5.3	–4.0	–4.9	–6.0	–4.4	–5.7	–4.7	–5.1
	With design standard evolution (%)									
CSIRO	–14.3	–13.6	–11.9	–10.8	–12.5	–14.2	–12.6	–13.2	–13.1	–13.1
NCAR	–5.5	–4.7	–7.2	–4.2	–5.8	–7.6	–3.7	–7.6	–4.3	–5.7
UKMO	–3.5	–3.1	–5.4	–2.7	–4.1	–5.7	–2.0	–5.8	–2.6	–3.9
IPSL	–4.7	–4.5	–4.7	–3.6	–4.4	–5.3	–3.9	–5.1	–4.2	–4.6
	With design standard evolution and flood investments (%)									
CSIRO	–14.0	–12.9	–15.1	–10.5	–14.2	–17.2	–10.0	–14.4	–13.3	–13.7
NCAR	–9.9	–8.9	–11.8	–7.2	–10.7	–13.4	–6.0	–10.7	–9.5	–10.0
UKMO	–9.5	–8.8	–11.8	–7.0	–10.6	–13.5	–5.6	–10.9	–9.1	–9.8
IPSL	–8.1	–7.6	–10.2	–6.0	–9.2	–11.8	–4.6	–9.1	–8.0	–8.5

Source: Simulation results from the CLIROAD model linked to the DCGE model.

Table 3. Comparison of CLIROAD Results When Run Standalone and Linked to the DCGE

	Kilometers		*Ratio to base*		
	Standalone	*DCGE*	*Standalone*	*DCGE*	*DCGE/Standalone*
BASE	124,010	124,010	1.00	1.00	1.00
CSIRO	109,993	105,653	0.89	0.85	0.96
NCAR	115,748	113,581	0.91	0.92	0.98
UKMO	121,433	117,680	0.98	0.95	0.97
IPSL	118,267	117,680	0.95	095	1.00
	With design standard evolution				
CSIRO	111,997	107,704	0.90	0.87	0.96
NCAR	118,978	117,000	0.96	0.94	0.98
UKMO	122,910	119,179	0.99	0.96	0.97
IPSL	119,002	118,367	0.96	0.95	0.99
	With design standard evolution and flood investments				
CSIRO	111,143	106,960	0.90	0.86	0.96
NCAR	114,103	111,657	0.92	0.90	0.98
UKMO	115,949	111,831	0.93	0.90	0.96
IPSL	114,618	113,528	0.92	0.92	0.99

Source: Simulation results from the CLIROAD model in standalone and linked to DCGE modes.

Table 4. Difference in Growth Rate of Real Absorption from BASE

		2003–50	*2010s*	*2020s*	*2030s*	*2040s*
Baseline	*BASE*	*2.117*	*1.567*	*1.912*	*2.524*	*2.934*
+Yields and SLR	CSIRO	–0.048	–0.042	–0.079	–0.065	–0.001
	NCAR	–0.030	–0.026	–0.080	–0.080	–0.010
	UKMO	–0.059	–0.006	0.004	–0.065	–0.040
	IPSL	–0.026	0.004	–0.050	0.071	–0.026
+Transport and Hydro	CSIRO	–0.110	–0.082	–0.129	–0.139	–0.118
	NCAR	–0.060	–0.038	–0.105	–0.123	–0.063
	UKMO	–0.074	–0.005	–0.004	–0.089	–0.076
	IPSL	–0.031	0.008	–0.046	0.059	–0.045
+Design Evolution	CSIRO	–0.106	–0.082	–0.127	–0.132	–0.105
	NCAR	–0.051	–0.038	–0.101	–0.110	–0.041
	UKMO	–0.072	–0.005	–0.003	–0.086	–0.068
	IPSL	–0.032	0.008	–0.048	0.056	–0.045
+Flood investment	CSIRO	–0.110	–0.084	–0.123	–0.139	–0.113
	NCAR	–0.073	–0.053	–0.110	–0.134	–0.087
	UKMO	–0.095	–0.021	–0.016	–0.112	–0.117
	IPSL	–0.049	–0.001	–0.054	0.037	–0.083

Source: DCGE model.

around US$2.5 billion (in 2003 prices and discounted at 5% per year). This loss can be translated into an annual payment of approximately US$140 million per year using a 5% discount rate. The level of per capita absorption is about 5% below what it would otherwise be in 2050 in the absence of climate change in the worst afflicted scenario

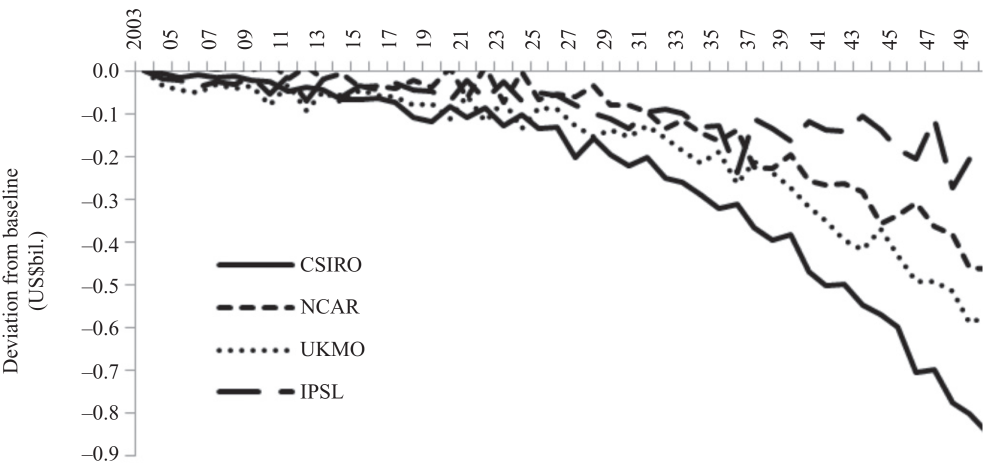

Figure 3. Reduction in Real Absorption Relative to BASE, 2003–2050

(CSIRO) and about 1.4% below what it would otherwise be in the least afflicted scenario (IPSL).

6. Conclusions

Empirical evidence indicates that the quantity and quality of a country's road infrastructure is a key determinant of its rate of economic growth. As a corollary, a lack of adequate infrastructure can be a constraining factor to growth. The possibility that climate change may accelerate the depreciation of infrastructure and divert resources away from other development objectives is therefore of concern. Here, we link a road infrastructure model (CLIROAD) to a dynamic computable general equilibrium (DCGE) model. The full incorporation of CLIROAD into a DCGE model represents a methodological improvement over previous analyses. The resulting DCGE model is able to estimate economy-wide costs and to compare road damages with other climate change impact channels, including crop yields, sea level rise, and hydropower generation. This integrated modeling framework was used to simulate four climate scenarios reflecting the full distribution of possible global and local climate change outcomes.

In the worst case scenario (CSIRO), damages from flooding are the primary cause of deteriorations in the road network. The economic model indicates that the economic costs of road damages may well exceed those of other climate change impact channels for Mozambique. We conclude that climate change through 2050 is likely to place a drag on economic growth and development prospects. The economic implications of climate change appear to become more pronounced from about 2030. Nevertheless, the implications are not so strong as to drastically diminish development prospects.

Left for future research is the issue of more intelligent placement of economic assets. As pointed out in the introduction, the large majority of the capital stock that will exist in 2050 (or even 2030) will be put in place over the coming decades. While the analysis conducted here does not favor a prophylactic policy of upgrading the road network, it should, in many instances, be reasonably obvious which portions of road are more likely to be subjected to flooding events. The concept extends well beyond roads. Indeed, the vulnerability profile of the large majority of the capital stock in 2050 is endogenous. By gradually channeling economic activity to areas less vulnerable to climate change (e.g. flooding events and sea level rise), the vulnerability of the economy can be greatly reduced, likely at very low cost. Simply accounting for the potential implications of climate change in decisions with respect to zoning and major public investments may be sufficient to substantially reduce the vulnerability profile in 2050 and beyond, when the implications of climate change are projected to manifest themselves with much greater force.

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