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Analysis

Long-Term Development Perspectives of Sub-Saharan Africa under Climate Policies

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ABSTRACT

Ambitious climate policy increases the cost of energy and therefore has important interactions with the prospects of development in the countries of Sub-Saharan Africa. These interactions include the potential for gain for the continent in the form of new trade opportunities and climate finance. In this paper we quantify the costs and benefits of climate policy in Sub-Saharan Africa. Using an Integrated Assessment Model, we consider key characteristics of the continent, including the favorable conditions for renewable energy. A newly designed scenario analysis allows identifying the main drivers of the results. We show that Sub-Saharan Africa could implement climate policy in line with the 2 °C target at roughly net zero costs if the international community follows up on its commitment towards supporting developing countries as declared in the Paris Agreement. Sub-Saharan Africa could become an important supplier of energy from biomass and could thus even benefit from more ambitious climate policy due to higher demand for this source of energy. The absence of a painful trade-off between short-term development and long-term climate stabilization could provide policy-makers with a much richer policy option space than previously considered. One such option is to link climate policy with poverty reduction through, for example, the provision of clean electricity.

1. Introduction

Does climate policy slow economic growth of countries in Sub-Saharan Africa? The answer to this question largely determines the incentives in this world region for participation in ambitious climate policy regimes. Turning away from proven development pathways based on fossil fuels requires costly additional investments into the energy system. Nevertheless, large renewable energy potentials, in particular for solar energy, and international technology diffusion could ease the transformation towards a low carbon economy and thus facilitate the adoption of emission reduction commitments. Additionally, countries in Sub-Saharan Africa could benefit from interactions with other world regions in the form of climate finance, international technology policies, and exports of bioenergy. While Sub-Saharan Africa consists of very heterogeneous countries, we consider a focus on the region as a whole a useful starting point for understanding the implications of an ambitious global climate policy regime.

In this paper we provide an aggregate and quantitative assessment of ambitious climate change mitigation on economic development in Sub-Saharan Africa. This assessment includes costs, in particular for the low-carbon transformation of the energy system, and benefits like climate finance and bioenergy trade. We take the renewable energy potential of Sub-Saharan Africa, international fossil fuel markets, and technology diffusion from other world regions into account. We find costs and benefits of climate change mitigation to be on the same order of magnitude, allowing Sub-Saharan Africa to participate in global mitigation efforts at roughly net zero costs. Additional benefits of climate policy would result from avoided climate impacts, which are not even taken into account in this study. Economic output is certainly not the only concern for decision makers in Sub-Saharan Africa, but a comparatively strong economy will help governments to face other challenges as formulated in the Sustainable Development Goals for example.

As a first contribution, we spell out the costs and benefits that are largely determined by the degree of international cooperation: countries in Sub-Saharan Africa benefit from rising demand for biomass on

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international markets under climate policies and from international burden sharing agreements based on equal emissions allowances per capita. Second, while a limited degree of international cooperation on climate and technology policies raises the costs of reaching climate targets globally, countries in Sub-Saharan Africa may by contrast experience lower costs, though associated with increased inequality in the intergenerational distribution. Third, potentially very regressive effects due to rising fuel prices highlight the need for careful climate policy implementation and complementary policies within countries.

Cost-effectiveness analyses using Integrated Assessment Models (IAM) indicate that climate stabilization goals can be achieved at moderate GDP losses in global aggregate (Kriegler et al., 2014). Some of these studies spell out the regional losses and gains underlying the aggregate global losses (Tavoni et al., 2015; Aboumahboub et al., 2014; Luderer et al., 2012). Only very few studies give detailed consideration to individual regions. Calvin et al. (2016) and Lucas et al. (2015) analyze the effect of economic growth on future global energy demand and emissions under different baseline and climate policy assumptions for Sub-Saharan Africa. This paper presents the first IAM-based study with a particular focus on Sub-Saharan Africa. It quantifies the feedback of climate policy on economic growth in a set of scenarios and provides a breakdown into the different contributing factors.

In previous studies, four categories have been identified as major drivers of the net effect of climate change mitigation on development in Sub-Saharan Africa. First, if principles of global equity are considered (as the Paris Agreement has indicated that they will), countries in Sub-Saharan Africa can expect to benefit from financial transfers, for example in the form of climate finance (Jakob et al., 2015). Second, African countries can draw on low-carbon technologies developed by technology leaders (Collier et al., 2008). Third, many countries in Sub-Saharan Africa are well positioned to decarbonize their energy systems due to large endowments of hydro and solar power potentials (Collier and Venables, 2012; Pietzcker et al., 2014). Fourth, Sub-Saharan Africa has a large potential for producing biomass (Dasappa, 2011) that could be used domestically or sold on international markets. This paper quantifies the net cost of mitigation for Sub-Saharan Africa using REMIND, an IAM with high detail in the energy sector (Leimbach et al., 2010). While the four mentioned mechanisms affect a number of African countries we are aware that due to the heterogeneity of countries (e.g. differences in endowments with hydro power and biomass resources) our results will not hold for all of them.

Historically, development has been based on the use of fossil fuels (Smil, 2000; Fouquet, 2010; Jakob et al., 2012). How low-income countries can "leapfrog" an energy and emission intensive development phase and reach levels of high income with clean forms of energy use has been discussed intensively (Ward and Shively, 2012; Steckel et al., 2013). Marcotullio and Schulz (2007) find that developing countries today are using energy in a cleaner and more efficient way than their earlier predecessors. Concerning Africa in particular, Sokona et al. (2012) find that "Africa has the benefit of diverse experiences and models, both successful and failed ones, to assist it in fast-tracking energy pathways". We follow this literature in the general idea that development patterns can change over time and explore how Africa can take advantage of its unique situation.

The paper is structured as follows. In Section 2 we give a brief description of the model and the scenarios that are explored in the following sections. Scenarios are designed along the dimensions of ecological efficiency, international cooperation on climate and technology policy, and equity in international agreements. The discussion in Section 3 focuses on the comparison of economic costs Sub-Saharan Africa as a model region is confronted with in the different scenarios. The analysis also addresses distributional impacts of different burden sharing schemes. Section 4 explores the requirements of the energy system transformation, including an ex-post analysis of distributional effects of this transformation within the region. We end with conclusions in Section 5.

2. Model Description and Scenario Implementation

2.1. REMIND

REMIND is a global, multi-regional, energy-economy-climate model (Leimbach et al., 2010) used in long-term analyses of climate change mitigation (e.g. Bauer et al., 2012; Bertram et al., 2015). A detailed model description is provided by Luderer et al. (2015). The remainder of this section briefly introduces the model.

The world is divided into eleven model regions, one of which is Sub-Saharan Africa. This region contains all countries on the African continent except Algeria, Egypt, Libya, Morocco (incl. Western Sahara), South Africa, and Tunisia. It would be desirable to have resolution on a country level, but as climate change analysis requires a global model, the regional resolution is constrained by computational limitations (i.e. limitations of solving large-scale numerical models). We consequently focus on Sub-Saharan Africa as a single model region interacting with other regions in a global model.

The macro-economic core of REMIND is a Ramsey-type optimal growth model in which intertemporal global welfare is maximized. The model computes a unique Pareto-optimal solution that corresponds to the market equilibrium in the absence of non-internalized externalities. Model regions trade final goods, primary energy carriers, and in the case of climate policy, emissions permits. Macro-economic production factors are capital, labor, and final energy.

Economic activity results in demand for different types of final energy (electricity, solids, liquids, gases, etc.), determined by a production function with constant elasticity of substitution, and differentiated by stationary and transport uses. The energy system accounts for regional exhaustible primary energy resources through extraction cost curves. Bioenergy comes from different feedstocks: traditional biomass and first generation biomass, both assumed to phase out in the near future, as well as lingo-cellulosic residues and purpose-grown second-generation biomass. The regional biomass potential is represented by regional supply curves.[4] Accordingly, Sub-Saharan Africa has the second highest biomass potential – around 25% of the global potential (Klein et al., 2014, Fig.1). Global biomass supply is limited to at most 300 EJ per year in our model, motivated by biophysical limits (Smith et al., 2015), concern for food security (Popp et al., 2011), and potential negative side effects of large-scale biomass production (Creutzig et al., 2015). Non-biomass renewable energy potentials are reflected in detail on the regional level: Sub-Saharan Africa, for example, has an annual potential of solar energy for photovoltaic production of 200EJ with high capacity factors (Luderer et al., 2015, Fig. 5). Future solar power deployment depends on its costs, which for solar photovoltaics have recently been declining steeply (Walwyn and Brent, 2015; IRENA, 2016). In REMIND, investment costs for photovoltaics and concentrated solar power fall exponentially with their cumulative capacity, approaching floor costs. The modeling of solar power, including assumptions on storage technologies and sensitivities to cost assumptions, is described in detail in Pietzcker et al. (2014).

More than 50 technologies are available for the conversion of primary energy into secondary energy carriers as well as for the distribution of secondary energy carriers into final energy. Techno-economic parameters (investment costs, operation and maintenance costs, fuel costs, conversion efficiency etc.) characterize each conversion technology.

The model accounts for CO_2 emissions from fossil fuel combustion and land use as well as emissions of other greenhouse gases (GHGs). A reduced form climate model is used to translate emissions into changes of atmospheric GHG concentrations, radiative forcing, and global mean

[4] Biomass supply curves in REMIND are derived from the land use model MAgPIE (Lotze-Campen et al., 2008; Klein et al., 2014). Costs of biomass production hence include opportunity costs of some alternative land uses, e.g. using land for food production.

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