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Climate change and economic growth: An intertemporal general equilibrium analysis for Egypt

Abeer Elshennawy [a], Sherman Robinson [b], Dirk Willenbockel [c,*]

[a] American University in Cairo, New Cairo 11835, P.O. Box 74, Egypt

[b] International Food Policy Research Institute, 2033K St NW, Washington, DC 20006-1002, USA

[c] Institute of Development Studies at the University of Sussex, Brighton BN1 9RE, UK

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ABSTRACT

This study advances the state of the art in country-level computable general equilibrium analysis for climate change impact and adaptation analysis by incorporating forward-looking expectations. The analytic framework is used to explore the long-run growth prospects for Egypt in a changing climate. Based on a review of existing estimates of climate change impacts on agricultural productivity, labour productivity and the potential losses due to sea-level rise for the country, the model is used to simulate the effects of climate change on aggregate consumption, investment and income up to 2050. Available cost estimates for adaptation investments are employed to explore adaptation strategies.

The simulation analysis suggests that in the absence of policy-led adaptation investments, real GDP towards the middle of the century will be 6.5% lower than in a hypothetical baseline without climate change. A combination of adaptation measures, that include coastal protection investments for vulnerable sections along the low-lying Nile delta, support for changes in crop management practices and investments to raise irrigation efficiency, could reduce the GDP loss in 2050 to around 2.6%.

Further work along these lines for developing countries in climate change hotspot regions deserves a high priority on the research agenda in economic modelling.

1. Introduction

Unmitigated climate change poses potentially serious threats to the economic growth and poverty reduction prospects of developing countries with high exposure to biophysical impacts and limited adaptive capacity. Even under optimistic assumptions about the level and success of future global mitigation efforts, it is essential for these countries to integrate adaptation plans into their national development strategies to cope with the likely consequences of already unavoidable climate change. Rational adaptation planning requires a forward-looking quantitative assessment of climate change impacts on economic performance at sectoral and economy-wide level to enable comparisons of the prospective benefits and costs of conceivable adaptation measures.

To facilitate such economy-wide cost–benefit assessments of alternative adaptation strategies and to assess impacts in the absence of policy-led adaptation action, a number of country-specific recursive-dynamic multi-sector computable general equilibrium models for a range of developing countries have been developed and applied in recent years. Examples include Arndt et al. (2011) and Robinson et al. (2012) for Ethiopia, Arndt et al. (2012) and Arndt and Thurlow (2015) for Mozambique, Thurlow et al. (2012) for Bangladesh, World Bank (2010a) for Ghana, and Strzepek and Yates (2000) for Egypt.

Multisectoral CGE models allow translating long-run projections of the various biophysical climate change impacts into sectorally and regionally disaggregated economic shocks to model parameters. Their unique advantage is that the simulated economic responses take systematic account of intersectoral spillover effects and macroeconomic feedback effects arising from economy-wide input–output linkages and economy-wide system constraints. Moreover, the simulated results capture market-mediated endogenous autonomous adaptation responses by consumers and producers to the changes in relative prices and real incomes triggered by the climate shocks. The CGE approach also facilitates multi-scenario simulations to address the uncertainties surrounding long-run projections of climate change impacts.

Models of this type have been (and will be) used to inform assessments of total adaptation funding needs for developing countries

* Corresponding author: Institute of Development Studies at the University of Sussex, Library Road, Brighton BN1 9RE, UK. Tel.: +44 1273 915700.

E-mail addresses: ashenawy@aucegypt.edu (A. Elshennawy), s.robinson@cgiar.org (S. Robinson), d.willenbockel@ids.ac.uk (D. Willenbockel).

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under the emerging post-2015 global climate finance architecture (World Bank, 2010b), and the further development of these tools deserves a high priority on the research agenda in economic ex-ante modelling.

However, a recurring criticism of recursive-dynamic CGE models is that their treatment of investment and saving behaviour lacks rigorous theoretical micro-foundations. While intra-temporal (within-period) decisions of consumers and producers are based on static optimizing behaviour and respond optimally to changes in intra-temporal relative prices, their intertemporal saving and investment decisions are not derived from forward-looking intertemporal optimizing behaviour, and thus ignore information about expected future economic conditions.[1] A related weakness of recursive-dynamic CGE models is that the intertemporal stock-flow linkage between temporal current account imbalances and the intertemporal evolution of the net foreign asset position is commonly ignored.

The present study overcomes these shortcomings of existing country-level CGE models for climate change impact analysis by adopting an intertemporal general equilibrium approach with forward-looking agents. In contrast to the standard recursive-dynamic approach, in which climate shocks hit agents in the model by surprise, the intertemporal approach pursued here takes account of endogenous anticipative adaptation responses to expected future climate change impacts.

To demonstrate the practical feasibility of this advanced approach, the model is used to analyse the long-run growth prospects of Egypt in a changing climate. Due to the high concentration of economic activity along the low-lying coastal zone of the Nile delta and its dependence on Nile river streamflow, Egypt's economy is highly exposed to adverse climate change. With an estimated per-capita income of US$ 3200 and 25% of the population living below the national poverty line,[2] vulnerability is likewise high.

The following section outlines the model and its numerical calibration to a social accounting matrix that reflects the observed current structure of the Egyptian economy. Drawing on a review of existing estimates of climate change impacts on agricultural productivity, labour productivity and the potential losses due to sea-level rise for Egypt, Section 3 specifies and motivates the climate change impact simulation scenarios. Section 4 presents simulation results in the absence of policy-led adaptation investments. Section 5 considers stylized adaptation scenarios, Section 6 reflects briefly on sensitivity and limitations of the analysis, and Section 7 concludes.

2. The model

The determination of intertemporal saving and investment decisions in the model is essentially a multi-sector open-economy extension of neoclassical optimal growth theory in the Ramsey–Cass–Koopmans tradition, while intratemporal allocation decisions across sectors are determined by a standard static small open economy CGE model as described in full technical detail in Robinson et al. (1999). The operational model design draws upon the contributions to intertemporal CGE analysis and its applications by Go (1994), Mercenier and Sampaio de Souza (1994), Diao and Somwaru (2000), Elshennawy (2011) and Roe et al. (2010), but extends this class of applied models by incorporating population growth and technical progress.

In line with its theoretical pedigree, the long-run steady-state growth rate of the model is governed by labour force growth and the rate of technical progress, while climate impacts that affect savings and investment entail *level* shifts in the time paths of GDP, consumption and other macroeconomic aggregates without affecting the long-run trend growth rate.

The model distinguishes six sectors of economic activity: agriculture, oil, industry, construction, electricity and services. The sectoral disaggregation is governed by the corresponding aggregation structure of the empirical benchmark data set to which the model is numerically calibrated. Output is produced using intermediate inputs and primary factors of production which include labour and capital. To capture the impact of different policy scenarios on the labour market, two skill categories of labour are distinguished, production and nonproduction labour. For simplicity, the role of government is confined to tax collection. Tax revenue is redistributed to the household sector and government expenditure is treated as part of household consumption. The agents in the model are a representative household with infinite planning horizon, a representative firm in each of the production sectors, and the rest of the world, which is linked to the domestic economy via trade, transfer and capital flows. Markets are perfectly competitive. What follows is a description of the dynamic components of the model.

2.1. Consumption behaviour

The representative household receives labour and dividend income from firms as well as net transfer income from the rest of the world and the re-transfer of tax revenue. The household chooses the path of consumption that maximizes the intertemporal utility function

$$U_o = \sum_{t=0}^{\infty} N_t \ln\left(\frac{C_t}{N_t}\right)\frac{1}{(1+\rho)^t} = N_0 \sum_{t=0}^{\infty} ln\left(\frac{C_t}{N_t}\right)\left(\frac{1+n}{1+\rho}\right)^t \quad (1)$$

subject to the intertemporal budget constraint

$$\sum_{t=0}^{\infty} R_t P_t C_t \leq \sum_{t=0}^{\infty} R_t [wp_t LP_t + wn_t LN_t + TR_t + TX_t] + W_0 \quad (2)$$

and a no-Ponzi-game transversality condition, where C is an index of aggregate real consumption, $N = LP + NP$ is household size with LP and NP denoting production and non-production labour respectively, n is the rate of population and labour force growth, ρ is the pure rate of time preference,[3] P is the implicit consumer price index dual to C, wp and wn are the wage rates for production and non-production labour, TR denotes net transfer income from the rest of the world, TX is tax revenue, W_0 is initial financial net wealth of the household sector, which is equal to the total market value of the firms owned by the representative household minus the initial external debt owed to the rest of the world, and

$$R_t = \prod_{s=0}^{t} 1/(1+r_s) \quad (3)$$

is the discount factor where r denotes the world interest rate.

The first-order conditions for the maximization of Eq. (1) subject to Eq. (2) and the transversality condition, which ensures that the given initial debt does not exceed the present value of future current account surpluses, take the form

$$\frac{P_{t+1}C_{t+1}}{P_t C_t}\frac{1+\rho}{1+n} = 1 + r_t. \quad (4)$$

The economic intuition behind condition (4) is straightforward: Along the optimal path the household is indifferent between consuming

[1] For explicit statements of this criticism of the recursive-dynamic approach see inter alia Srinivasan and Go (1998), Babiker et al (2009), Lecca et al (2013), Fisher-Vanden et al (2013), and Bröcker and Korzhenevych (2013) who conclude that "these models lack internal consistency".Fankhauser and Tol (2005) and Lecocq and Shalizi (2007) provide systematic conceptual discussions of the channels through which climate change potentially affects aggregate economic growth in Solow-type growth models, Cass–Koopmans-type optimal growth models and endogenous growth models.

[2] World Bank WorldData Bank, accessed September 2014.

[3] See Willenbockel (2008) for a detailed discussion of the relationship between the subjective pure time preference rate of households and the pure social time preference rate in a utilitarian social welfare function within an overlapping generations setting. Much of the confusion in the recent controversy about the "appropriate" choice of the social discount rate in cost–benefit analyses of climate change mitigation efforts suffer from a clear conceptual distinction between these rates, as Stern (2008) points out correctly.

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