Climate Change, Agriculture and Gender in Latin America: a MIRAGE-CC approach

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Abstract

This paper seeks to provide a systematic analysis of the economic consequences of the impact of climate change on agricultural yields by 2050, with a special focus on Latin America. In this paper we combine climate models with a worldwide CGE model to analyze the economic impacts of climate change on Latin America (LAC). To achieve these goals, the MIRAGE-CC model is updated to focus on LAC countries and modified to include the gender dimension. Preliminary results show that climate change has a differentiated impact among countries in Latin America: while in Argentina and the rest of Latin American countries there is a positive impact on real income and agriculture production, Brazil and Central American countries are negatively affected. At the household level, we find significant changes in consumption patterns, especially in the rest of Latin American countries, where real consumption of vegetables increases above 8% depending on the scenario, and real consumption of oilseeds, wheat and maize decline significantly.

Keywords: Climate change, Latin America, gender

1. Introduction

Climate change typically involves changes in water availability and temperature - and both of these affect crop yields. Changes in crop yields in turn influence prices –of commodities as well as production factors. Changes in relative factor prices stimulate their reallocation in the economy and result in changes in sectoral specialization. Sectoral incomes will in turn be affected which, together with changes in sectoral specialization, will result in adjustments in sectoral demand and supply. These changes however, do not occur in a closed economy but at a global level with heterogeneous effects across countries and commodities. Comparative advantages evolve, trade patterns adapt and countries are affected by both the domestic effects of climate change and by changes in relative prices in world markets (terms of trade effects). Over time, considering income and current account constraints, production will be reallocated across sectors and across regions to adapt to the exogenous changes in yields. General equilibrium effects may mitigate or magnify the initial impacts.

This paper seeks to provide a systematic analysis of the economic consequences of the impact of climate change on agricultural yields by 2050, with a special focus on Latin America. Given the complex relationships described above, adequately modeling of the economy-wide effects of climate change requires linking of climate models (Global Circulation Models) to economy-wide models (computable general equilibrium or CGE models). In this paper we combine climate models with a worldwide CGE model to analyze the economic impacts of climate change on Latin America (LAC). First, we use IFPRI's IMPACT (International Model for Policy Analysis of Agricultural Commodities and Trade) framework to assess the effects of climate change (i.e. changes in water availability and temperature) on crop yields under the assumption of no changes in economic behavior. Subsequently we feed these exogenous changes in a global computable general equilibrium model (MIRAGE – Modeling International Relationships in Applied General Equilibrium) to assess the economic impact of climate change. For the purposes of this project MIRAGE was expanded to provide a more accurate description of land use and long-term dynamic issues: the MIRAGE-CC version. In addition, we introduced gender-differentiated factor markets to capture the gender consequences of climate change. MIRAGE-CC is also used to analyze the impact of different climate change scenarios under alternative trade and infrastructure policies.

To achieve these goals, the MIRAGE-CC model is updated to focus on LAC countries and modified to include the gender dimension. The initial dataset is based on GTAP8 and completed/updated with FAOSTAT, ILO, and IFPRI datasets on LAC (household surveys, and social accounting matrices). An extensive effort is dedicated to build robust macro-economic baselines for the LAC region (growth, technology, energy mix and efficiency) up to 2050. Evolution of crop yields in the baseline is based on the projections of the IMPACT model for irrigated and non-irrigated area (global coverage implemented at the IMPACT FPU units). The climate change impacts are introduced as a change in the land productivity to match the yield deviation computed in the crop model used by IMPACT.

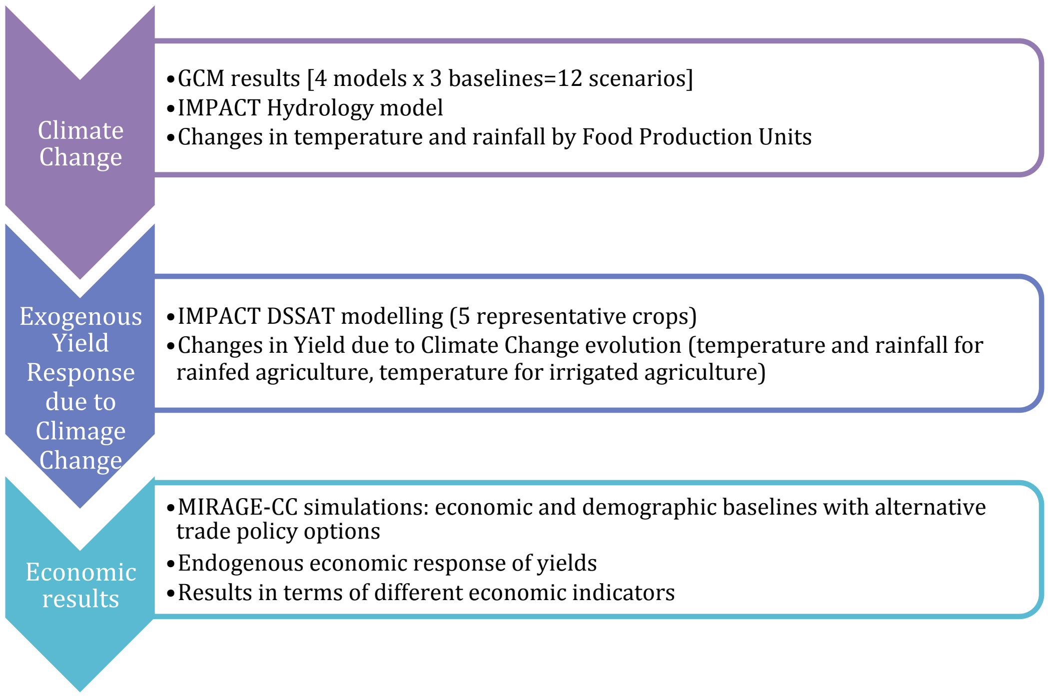
To achieve the needed focus on LAC countries, the model is run with a high level of geographical disaggregation for the region of interest. In particular, the model includes 20 LAC regions, 11 countries and regions in South America and 9 in Central America and the Caribbean islands. 12 additional regions will cover the rest of the world. Agricultural production units match IMPACT FPU.

The baseline scenario is consistent with the SSP2 "middle of the road" scenario (IIASA demographics, OECD GDP). We then run three scenarios of climate change, assuming different emissions pathways (temperature changes) and/or GCM / crop model combination; and three scenarios of regional integration policies, with a focus on trade policies and infrastructure reforms.

Preliminary results show that climate change has a differentiated impact among countries in Latin America: while in Argentina and the rest of Latin American countries there is a positive impact on real income and agriculture production, Brazil and Central American countries are negatively affected. At the household level, we find significant changes in consumption patterns, especially in the rest of Latin American countries, where real consumption of vegetables increases above 8% depending on the scenario, and real consumption of oilseeds, wheat and maize decline significantly. Looking at some distributional effects of climate change, we also find that the impact on unskilled workers real wages, which can be taken as a proxy for poor people income, is negative for Brazil and Central American countries. This is logical since unskilled labor force is directly impacted by the change in agriculture productivity and yield of land, since this factor is largely used by this sector. Trade policies magnify the effect on unskilled wages.

2. Methodology

Modeling the economic impacts of climate change by 2050 requires combining different models. The integrated methodology for climate change analysis using MIRAGE is depicted in figure 1.



Taking results from different climate models (Global Circulation Models, GCM) about the probable evolution of temperature and rainfall, we use the set of IFPRI tools gathered under the IMPACT framework to assess the effects of changes in water availability and temperature on yield assuming economic behavior as constant. Then, we feed these exogenous changes in a modified MIRAGE global computable general equilibrium (CGE) to assess the overall economic consequences of these evolutions. The CGE is also used to analyze these different climate change scenarios with different socio-economic baselines including alternative trade policies.

a. The IMPACT framework

b. The MIRAGE model for Climate Change Analysis

To assess the economy-wide effects of global climate changes, the CGE provides the most appropriate framework. Climate change modifies agricultural productivity and will have a direct impact on agricultural commodity prices and factor prices. Through the factor price channels, factors will be reallocated in the economy and as a result sectoral specialization will change. In addition, incomes will be affected and demand behavior will be modified. Demand will also be affected by change in prices and food consumption, even if inelastic, will be impacted as well. Since agricultural products (crops but also fibers and animal products) are important inputs for many sectors, changes in their prices will affect other sectors. All these channels require the use of a CGE model that is capable of tracking these changes. In addition, these changes do not occur in a closed economy but at a global level with heterogeneous effects across countries and commodities. Comparative advantages evolve, trade patterns adapt and countries are affected by both the domestic effects of climate change and by the modifications of relative prices in world markets (terms of trade effects). Over time, considering income and current account constraints, production will be reallocated across sectors and across regions to adapt to exogenous changes in yields. Depending on the specific situation, general equilibrium effects will mitigate or magnify the initial impacts. For example, capital may leave agriculture due to the negative shock on returns, accelerating the fall in the yields and production levels in one country; or alternatively may move to this sector attracted by high prices thus compensating, at least partially, for the exogenous reduction in yields. This is the reason why a multi country, multi sector, dynamic CGE model is needed. The analysis in this paper uses an upgraded and adapted version of the MIRAGE model. Below follows a description of the core MIRAGE model as well as of the modifications that are required to enable to use the model for long term projections. In terms of trade analysis, the choice of the Armington assumption (differentiating goods by country of origin) is important and a major difference when compared with most partial equilibrium analysis frameworks, including the IMPACT model. The Armington assumption implies imperfect price transmission between international and domestic markets, and specific trade patterns at the bilateral level. On the contrary, partial equilibrium assuming perfect substitution implies a single world market for each agricultural commodity, and unilateral net trade flows (except for spatial trade models). Nevertheless, while the latter approach has certain advantages in terms of ease of tracking quantities and simplifying the modeling framework, the empirical literature (see Villoria 2009 for a recent analysis) strongly argue in favor of the features that result from adopting the Armington assumption: price transmission is imperfect, there is no such thing as a single world market, and geography, as well as history, matter for explaining trade patterns.

Generic features of the MIRAGE model

MIRAGE is a multi-sector, multi-region Computable General Equilibrium (CGE) model for trade policy analysis. The model operates in a sequential dynamic recursive way: it is solved for one period, and then all variable values, determined at the end of a period, are used as the initial values for the next period. Macroeconomic data and social accounting matrixes, in particular, are derived from the GTAP 7 database (see Narayanan, 2008), which describes the world economy in 2004. At the supply side, the production function in each sector is a Leontief function of value-added and intermediate inputs: one output unit needs for its production x percent of an aggregate of productive factors (labor, unskilled and skilled; capital; land and natural resources) and (1 – x) percent of intermediate inputs. The intermediate inputs function is an aggregate CES function of all goods: this means that substitutability exists between two intermediate goods, depending on the relative prices of these goods. This substitutability is constant and at the same level for any pair of intermediate goods. Similarly, in the generic version of the model, value-added is a constant elasticity of substitution (CES) function of unskilled labor, land, natural resources, and of a CES bundle of skilled labor and capital. This nesting allows the modeler to introduce less substitutability between capital and skilled labor than between these two and other factors. In other words, whenever the relative price of unskilled labor increases, this factor is replaced by a combination of capital and skilled labor, which are more complementary. Factor endowments are fully employed. The only factor whose supply is constant is natural resources with a few exceptions detailed later. The supply of capital is modified each period because of depreciation and investment. Growth rates of labor supply are fixed exogenously. Land supply is endogenous; it depends on the real remuneration of land. In some countries land is a scarce factor (for example, Japan and the EU) reflected in a low elasticity of supply. In others (such as Argentina, Australia, and Brazil) land is more abundant and the supply elasticity is higher. Skilled labor is the only factor that is perfectly mobile. Installed capital and natural resources are sector specific. New capital is allocated among sectors according to an investment function. Unskilled labor is imperfectly mobile between agricultural and nonagricultural sectors according to a constant elasticity of transformation (CET) function: unskilled labor's remuneration in agricultural activities is different to that in nonagricultural activities. This factor is distributed between these two series of sectors according to the ratio of remunerations. Land is also imperfectly mobile between agricultural sub-sectors. In the MIRAGE model there is full employment of labor; more precisely, there is a constant aggregate employment in all countries (wage flexibility). It is quite feasible to assume that total aggregate employment is variable and that there is unemployment; but this choice greatly increases the complexity of the model, so that simplifying assumptions have to be made in other areas (such as the number of countries or sectors). This assumption could amplify the benefits of trade liberalization for developing countries: in full-employment models, increased demand for labor (from increased activity and exports) leads to higher real wages, such that the origin of comparative advantage is progressively eroded; but in models with unemployment, real wages are constant and exports increases are larger. Capital (either domestic or foreign) in a given region is assumed to be obtained by combining intermediate inputs according to a specific combination. The capital good is the same across sectors. The version of the MIRAGE model used in this paper assumes that all sectors operate under perfect competition, there are no fixed costs, and prices equal marginal costs. The demand side is modeled in each region through a representative agent whose propensity to save is constant. The rest of the national income is used to purchase final consumption. Preferences between sectors are represented by a linear expenditure system – i.e. constant elasticity of substitution (LES-CES) function. This implies that consumption has a non-unitary income elasticity; when consumer's incomes are augmented by x percent, consumption levels are not systematically raised by the same percentage, other things being equal. The sectors' sub-utility functions used in MIRAGE are a nesting of four CES-Armington functions that define the origin of the goods. Macroeconomic closure is obtained by assuming that the sum of the balance of goods and services and foreign direct investments (FDIs) is constant.

MIRAGE-CC

c. Introducing gender in MIRAGE-CC

One final modification to the model regards the differentiation among male and female workers. This feature is important in the case of Latin American countries. We split the usual skilled-unskilled labor data included in GTAP database into female and male labor respectively, obtaining four labor categories. To do so, we follow the work by Dimaranan and Pace (). Gendered wage data by occupation (ISCO) is sourced from Harsch and Kleinert (2011) while gendered employment data by industry (ISIC) and occupation (ISCO) is sourced from the ILO Yearbook.

3. Simulations and results

To be included

4. Concluding remarks

To be included