Groupe de Recherche en Économie et Développement International

Cahier de recherche / Working Paper
09-11

Distributional impact of developed countries CC policies on Senegal : A macro-micro CGE application

Dorothée Boccanfuso

Antonio Estache

Luc Savard

UNIVERSITÉ DE SHERBROOKE

Distributional impact of developed countries CC policies on Senegal : A macro-micro CGE application

DOROTHÉE BOCCANFUSO[*], ANTONIO ESTACHE[ι], AND LUC SAVARD[**]

MAI 2009

Abstract

In this paper we present an analysis of distributional impact analysis of climate change policies envisaged or implemented to reduce greenhouse gasses emissions on Senegal. We consider policies implemented in developed countries (namely the ones engaged in the Kyoto protocol) and their impact on a developing country. Moreover, we simulate a diminishing productivity of land used in agriculture as a potential result of CC for Senegal. This country is exposed to the direct consequences of CC and is vulnerable to changes in world prices of energy given is lack of substitution capacity. According to Winters et al (1998), countries with this profile will bear the greatest burden of CC and its mitigating policies. Our results reveal slight increases in poverty when world price of fossil fuels increase and the negative impact are amplified with decreases in land productivity. However, subsidizing electricity consumption to protect consumers for price world price increases in fossil fuels provides a weak cushion to poverty increase.

Keyword: Global warming, environmental policies, income distribution, developing countries.

JEL: Q53, D58, Q54, Q58, I32

[*] GREDI, Department of economics, Faculté d'administration, Université de Sherbrooke, Sherbrooke Canada

[ι] Senior economic advisor at the World Bank and a member of the faculty of the European Centre for Advanced Research in Economics and Statistics at the Free University of Brussels.

[**] Corresponding author, GREDI, Department of economics, Faculté d'administration, Université de Sherbrooke, Sherbrooke Canada (luc.savard@usherbrooke.ca)

1. Introduction

Policies to reduce Global warming are being implemented in many countries that signed the Kyoto protocol to reach its goals. Other countries are also implementing or envisaging policies to reduce greenhouse gas emissions. Most of the reforms proposed to achieve the goals of the Kyoto protocol or reducing greenhouse gasses (GHG) imply internalizing externalities. These policies will directly or indirectly contribute to increasing the production cost of goods that contribute to global warming as well as the price of the goods. This increase in cost and price should contribute to modify consumer and producer behaviour that will allow for the reduction of these GHG. Moreover, the change in prices of these goods relative to other goods produced in the economy will significantly modify factor allocation in the economy and households welfare through a change in consumer prices and factor payments. If these impacts are negative and affect large portions of vulnerable groups of population, the implementation of environmental policies to reduce GHG could come in conflict with achievements of millennium development goals if appropriate measures are not taken to compensate the losers in this process. In this context and in light of the marginal contribution of some developing countries to GHG, many will chose not to implement GHG reduction policies. However, these countries will not be isolated from the policies implemented in developed countries and will be the first one affected by the global warming with significant losses in agriculture productivity.

The microeconomic burden of these measures will depend on many factors. Among the important factors are natural resource endowment, factor endowment, structural characteristics of the economies, consumption and trade patterns of the country. Boccanfuso et al (2008b) provide a review of characteristics that will play a role in determining the distributional impact of GHG reduction policies in developing countries. The impact of the policies will not be confined to the country of application. If a large country in terms of size of the economy and if a large number of countries simultaneously implement similar policies or policies having the same effect on prices and supply, the impact will be felt on world markets of goods directly or indirectly concerned by the policy. Hence, world demand, supply and prices will or could be significantly affected.

Most developing countries have been mostly observers in terms of implementation of policies to tackle global warming. The Kyoto protocol does not require these countries to contribute the reducing greenhouse gasses. However, they are not observers when considering the impact of these reforms. Considering that the sectors most strongly affected by greenhouse gasses emission reduction policies are the energy, natural resources and agricultural sectors and that many developing country economies are dependant on food and energy imports and they export mostly agricultural goods natural resources, we can assume that they are extremely vulnerable to important changes on world market for these goods. In addition to this, poor and vulnerable groups in developing countries are mostly employed in the agricultural sectors and agricultural goods constitute a large portion of their total expenditure. Moreover, we are observing an increase in concern (von Braun 2007 and Doornbosch and Steenblik 2007) of the negative impact of increasing prices for food staples on the welfare of vulnerable groups in developing countries[1].

A good example to illustrate this problem is the subsidies in the biofuels sector which are producing significant impact on world prices of inputs to these biofuels. As stated by von Braun

[1] Important non-governmental organizations such as OXFAM and Friends of the Earth have taken strong position against the promotion of biofuels as their consequences on poor populations of developing countries could be disastrous (Oxfam 2007).

(2007) demand for cereal used for food and feed has increased by 4 and 7 percent respectively since 2000. On the other hand, the demand for cereals destined to industrial production has increase by more than 25% and in the United States alone, the corn used for the production of ethanol has increased by 250% between 2000 and 2006. Biofuels in general and ethanol in particular have been the main target recently but other environmental policies to reduce the emission of greenhouse gasses will also produce an impact on the welfare of poor households in developing countries through demand and supply changes on world market.

For example, command and control policies also contribute to increases cost of energy and natural resources. On the other hand, *cetaris paribus* strong increases in green taxes could produce a strong reduction in demand in developed countries and contributing to reduce the pressure on the world demand for the goods concerned[2].

One of the most powerful methodologies to analyse the impact of environmental policies on welfare to clearly identify the winners and losers of such reforms are the computable general equilibrium (CGE) models (Bergman 1991, Winters *et al* 1998, Fullerton and Heutel 2007, Arrar et al (2008) among others). Bergman 1991, pioneering work to analyse environmental policies in a CGE context, illustrated the importance of capturing the general equilibrium effects and distinguishing winners and losers of such policies albeit the microeconomic distributional impact are not dealt with in the paper. Winters *et al* (1998) provide an interesting comparative analysis of economic and welfare analysis of CC on developing countries. Three archetype models representing an Asian, African and Latin American country show that these countries suffer on

[2] It is important to highlight that the effects on world markets for food staples, natural resources and energy are taking place simultaneously with other factors such as the strong growth of the world economy.

an aggregate basis and low substitution possibilities in Africa leads to the worst effects. Once again, this analysis focuses on aggregates and not on micro distributional issues. More recently, O'Ryan et al (2003) analyse national CC mitigation policies in Chile. They show that policies reducing GHG by 50% can have significant macroeconomic distributional impact. Dessus and O'Connor (2003) use a CGE model to analyse reduction of CO_2 emissions in Chile and health benefits and find that the welfare lost are partly compensated by health benefits. Timilsina (2007) apply a CGE model to the Thailand economy and analyse various tax instruments to reduce GHG and measures which revenue recycling scheme produces the weakest welfare lost.

On the other hand, since the late 1990 an important literature has emerged to use CGE modelling for poverty and distributional analysis. This line of research includes Decaluwé et *al.* (1999) and Cogneau and Robilliard (2000) among others. These papers have been followed by a large number of applications[3]. Many analysts have investigated trade reforms (see Hertel and Reimer (2005)) and more recently price reforms in utilities with these macro-micro CGE methodologies (see Boccanfuso et al 2008a and Boccanfuso et al 2009). In this paper we will exploit the CGE modeling approach for distributional impact analysis to analyse CC mitigating policies and CC impact in Senegal.

The paper is organized as follows. The next section briefly summarizes the characteristics of Senegal in terms of climate and activities and the possible effects of climate change in the country. Section 3 provides a presentation of the CGE model used in the analysis. We follow

[3] For an interesting review, the reader can consult Hertel and Reimer (2005).

with a presentation of our distributional impact analysis and concluding remarks are presented in Section 5.

2. The country of application

Senegal is at the most western part of the African continent. It has a 700km coastline and it benefits from a marine current from the Atlantic ocean. The maritime current is beneficial for agriculture on the coastline but its flat topology does not provide a barrier for the Harmattan winds coming from the Sahara Desert. This wind brings hot air, dust and droughts with it. The country has two main seasons, with the dry season spanning from November to May and the rain season (hivernage) from June to October.

2-1 Environmental policy in Senegal

Senegal was part of the countries that signed the United Nations CC agreement in Rio in 1992 and ratified it in parliament in Senegal in 1994. It then created the « *Ministère de l'Environnement et de la Protection de la Nature (MEPN)* » from which emerged two structures: The superior council for the environment and natural resources (CONSERE) and the National commission for sustainable development. These institutions have the mandate to support the government by responding to goals of the protocol. Hence, by signing the protocol, Senegal is committed to tackle efficiently negative impact of CC even if it is not bound to reduce its emissions. The country is also committed to produce an inventory of all GHG emitted and two of those inventories have been produced for 1991-1994 and the second one for 1995.

In 1999, the MEPN presented and National implementation strategy (SNMO) for the Kyoto protocol. The main goal of this strategy was to offer a framework to consolidate the knowledge on CC; and explore policies and measures that could integrate concerns on CC for a national sustainable development. In this document, the authors state that perceivable CC changes in

2050 will be the result of GHG. In this context, GHG inventory in Senegal and sectoral vulnerability in Senegal are a key challenge. This should facilitate the implementation of mitigation and adaptation strategies in the future.

3. macro/micro CGE model for distributional impact analysis

Since the late 1990s researchers have been using CGE principles to develop and apply macro–micro models in developed and developing economies. The impetus for this growing body of research was recognition of the unsuitability of the CGE representative agents approach (CGERA) for analysis of poverty and income distribution. CGERA does not allow researchers to taken into account within-group changes in income distribution, even though studies (Huppi and Ravallion 1991 and Savard 2005, for example) have shown that such changes can be greater than between-group inequality changes. This is true both for the static measure and for variations following policy simulations. Savard (2005), comparing the CGERA approach to a CGE microsimulation approach (a top–down/bottom–up approach to be discussed later), demonstrated that the results of poverty and income distribution analysis can be completely reversed by taking into account within-group distributional effects.

The CGERA approach divides households into groups, choosing a representative household for each group and using that representative household in the CGE model. Changes in the income of all households in each group are then inferred from the change of income of the representative household. But, as noted, ignoring within-group income redistribution can lead to misleading conclusions. A second approach, proposed by Decaluwé *et al* (1999) and applied by Cogneau and Robilliard (2000), and Gørtz *et al* (2000), is the CGE integrated multi-household approach (CGEIMH). This method incorporates a large number of households from a household survey (and sometimes all of them) into the CGE model. The approach takes into account within-group distributional effects and has the further advantage of providing coherence between the micro and macro parts of the model.

The third approach is referred to as the CGE micro-simulation sequential method (MSS) and could be subdivided into two variants. The first one, micro-accounting, is formally presented by Chen and Ravallion (2004) and extensively applied in recent years[4]. The second one, proposed by Bourguignon, Robilliard and Robinson (2005), consists in integrating at an individual level rich micro behaviour observed at a household level such as consumption or labour supply. The general idea of the MSS approach is that a CGE module feeds market and factor price changes into a micro-simulation household module. The main criticism levelled at this approach is that the micro-feedback effect is not fully taken into account: the question has been raised in two literature reviews of macro-micro modeling for poverty analysis (Hertel and Reimer (2005) as well as Bourguignon and Spadaro (2007). However, Bourguignon and Savard (2008) found that the loss of information associated to using the MSS approach can be relatively small and policy conclusions were robust between the two approaches[5].

Here we applied the CGEMSS approach. The main reason for our choice is that we simulate conditional transfers to poor households in some scenarios, and such conditional transfers are difficult to handle using a standard CGEIMH model.[6]

Before describing the model in detail it is important to highlight the links between CC mitigation policies and CC impact and household welfare. The policies will essentially be

---

[4] Among early applications of this approach are Vos and De Jong (2003) and King and Henda (2003).

[5] Bourguignon and Savard (2008) comparative analysis between the IMH and MSS approaches was applied on the Filipino economy. In there study, the labour supply was endogenous and the largest portion of the gap in the results obtained from the two approaches came from the labour supply. The labour supply will be held constant in our application.

[6] Solving these models using the GAMS software with the standard algorithm, one cannot introduce conditional transfers within the model. The CGEMSS approach offers more flexibility without great loss of information, because our macro and micro database are fully coherent, and all household accounts have been balanced.

captured by price increases and external shocks on agricultural production. These simulations will be transmitted to household incomes through mechanisms such as variations in market prices of consumer goods and services and, more significantly, on factor payments for production factors (wages, rate of return on capital and land). Between the simulation and the appearance of price changes, many interactions take place between production sectors as factors relocate. The structure of the economy, the behaviours of economic actors, and rules of macroeconomic closure also play important roles. To capture the impact of these simulations on the welfare of individual households, it is important to incorporate details of the question at hand, in this case Senegal's economic structure and functioning of the nation's overall economy.

The model we used is an adaptation of the model used by Boccanfuso et al (2009) to assess the reforms of the electricity sector in Senegal. In order to capture the impact of simulations on individual household welfare, we integrated a detailed view of the electricity sector, with an equally detailed view of the Senegalese economy given the importance of the use of fossil fuels to product electricity in Senegal. To start, we isolated electricity production from the electricity, gas, and water sector found in the original input/output table in the ESAM data. Access to Senelec's financial accounts allowed us to do this. The rest of this section provides a detailed presentation of the model we used.

For all sectors except electricity, total production of a sector (*XS*) is made up of fixed shares (Leontief shares) of value added (*VA*) and intermediate consumptions (*CI*). *VA* is a combination of composite labour (*LD*) and capital (*KD*) related using a Cobb-Douglas function. Producers minimise their cost of producing *VA* subject to the Cobb-Douglas function. Optimal labour demand equations are derived from this process. Labour is then decomposed into skilled and unskilled labour, with combinations of the two factors determined by the constant elasticity of the substitution function (CES). This assumption allows for sector-specific elasticity of substitution. We have assumed that capital is not mobile between sectors, as it is difficult in the short to medium term to convert capital for use in another sector.

The structure of the electricity market is modelled with rigidities of factors (capital and labour are exogenous for this sector) and market price. Consistent with the reality faced by utilities in Senegal, we assume that the electrical utility is subject to price controls, so that the average tariff and tariff structure are givens. This implies that Senelec will produce electricity based on the constraint of a production function and that the quantity of electricity supplied will respond to demand. Since the factors are fixed, Senelec increases its output by increasing its purchases of the intermediate inputs (such as diesel fuel) that it uses to produce electricity. The output of the sector is therefore demand driven, given a fixed price on the market. In the model, production sectors consume electricity as an intermediate input, and households consume it as final consumption; these quantities are drawn from the household surveys.

Ours is a model of a small open economy to which world prices of imports and exports are exogenous. We posed the Armington hypothesis (1969) for import demand, whereby domestic consumers can substitute domestically produced goods with imports (imperfectly) according to an elasticity of substitution that is sector specific. Where local consumers have no preference between imported and local goods, we will have a high elasticity of substitution; inversely, the elasticity of substitution is low where consumers prefer one good over the other. The relative price of the two goods is the other determinant of the ratio of demand for imported goods versus demand for local goods. On the export side, producers can sell the goods on the local market or export their production and are influenced by relative prices on each market and by their elasticity of transformation of the good for one or the other market.

We include in the model all 3,278 households covered in ESAM-I in order to capture intra-group changes in the distribution of income. Because we use all households of the survey, there is no need to specify household groups within the CGE model.[7] Our household income equations are consistent with the structure observed in ESAM-I.

The initial factor endowments for labour and capital, as well as the endogenous transfers between agents, are important determinants of how household welfare changes under various policy simulations. In this model, factor allocations are exogenous; factor payments, endogenous. The other important element is the consumption structure of households, which will be affected by the price changes in the policy simulations. As capital is fixed by sector, we generate 18 endogenous capital payments and 2 wages (skilled and unskilled). Dividends paid to households are also endogenous and are dependent on a firm's income after taxes. Inter-agent transfers are considered endogenous. The households that are heavily dependent on those transfers turn out to be very vulnerable to fluctuations in this variable. The other sources of income are exogenous transfers from government and the rest of the world, which are the last two agents in the model.

The income of private firms is computed as income less dividends plus government subsidies and transfers from the rest of the world. We consider Senelec as an agent in the model, separate from the government and private firms. In the baseline period, we used information from before the first privatization to reflect the situation at Senelec. In 1998, one year before the privatization and for 1 year after the first privatization, the government provided annual subsidies to Senelec around 4 billion CFA francs (CRSE 2003)[8]. This is the financial situation we used for the reference period. An increase in the price of electricity would help reduce the subsidy, which

---

[7] Household decomposition can be done independently of the modeling exercise after policy simulations.

[8] In fact it varied from 4 to 6 billion CFA francs during the period. We used the 4 billion in our model.

is endogenous in the model and determined by the difference between the revenues generated from sales of electricity and the cost of producing it.

Government revenue is made up of taxes on producers, customs duties, individual and business income and sales taxes, and transfers from the rest of the world (budgetary assistance and other foreign grants). The government spends its budget on public goods, transfers to households, subsidies to private firms, transfers to the rest of the world, and subsidies to public utilities, such as Senelec.

The household demand is differentiated in the household in the two modules. This is done to capture a specific feature of household behaviour in Senegal for a petroleum subproduct and since we did not have information to disaggregate the CGE module on this item. Let us first describe the behaviour modelled in the CGE module before describing the difference in the microsimulation household module. The demand function is derived from a utility maximization process (Cobb-Douglas utility function), which produces demand functions in which each good has a fixed value share. Households have specific marginal share parameters based on observed data in the household survey. At the microsimulation household model level, we integrate a behaviour observed for household cooking energy consumption. Two main modes of energy are used as is observed in household survey data. Butane/propagne gas is used for cooking and is the source of energy for cooking and the other source of energy is wood charcoal. This charcoal is produced by the forestry sector and comprises for 56% of energy use (Ministère de l'environnement 2006). An increase in use of this source of energy contributes to an important deforestation problem in Senegal with a total forest degradation rate at 0.56% and increasing (Mongabay (2009)). Hence, change in the relative price for these two goods will induce relatively strong substitution in energy consumption given the low cost of moving from one to the other for energy needs. The two sources of energy can also be used for heating during the coldest months of the year (January and February). We model this substitution behaviour with a CES function from which we derive optimal demand for these two goods to constitute a composite energy good. The trade-off between the two goods is dependent of the elasticity of substitution, relative price of the two goods and initial shares[9]. The welfare changes are computed by taking into account this consumption behaviour with the equivalent variation to capture the impact of simulations on income as well as on the cost of household consumption basket.

Investment demand is also specified with a fixed value share function. Our price equations are standard. We used the GDP deflator as a price index, and, as stated earlier, international prices (imports and exports) are exogenous. Accordingly the country has no control over the prices applied on the world market. The only specific item in terms of prices, as mentioned earlier, is that prices for utility services are exogenous to reflect the observed facts.

Our model equilibrium conditions for non-utility markets are also standard. The commodity market is balanced by an adjustment of the market price of each commodity. The labour market is segmented and balances out with an adjustment of the nominal wage on each of the respective markets (skilled and unskilled). It is therefore possible for workers to move from one sector to the other, but not from one market to another. Labour supply in each of the markets is fixed, and there is no unemployment.[10] The price index and the nominal exchange rate are fixed, and hence the current-account balance is left endogenous. With regard to the equilibrium

[9] We use a relatively high elasticity of substitution of 5 but performed sensitivity analysis on this parameter.

[10] This does not mean that we assume that zero unemployment in the economy but rather that unemployment is exogenous to the model.

of savings and investment, total investment adjusts to the sum of the savings of all agents in the model.[11]

The diagnostic of poverty and inequality changes is based on two indexes commonly used in macro–micro modelling. The poverty index we chose is the P_α index of Foster, Greer, and Thorbecke (1984).[12] The CGEMSS model generates post-simulation changes in welfare for each household in the model. The changes in welfare are then used to compute changes in poverty. Target groups are defined independently of the CGE modelling exercise, and poverty analysis can be performed for the reference period and after simulations. This approach, standard in macro–micro CGE analysis, has the advantage of taking into account price and income effects simultaneously.

4. Simulation and distributional impact

In the paper we analyse three simulations. The first one is related to CC policies applied in developed countries that would results in an increase in price of fossil fuels. As this is the main input in the energy production in Senegal, it will have direct and indirect effects on the Senegalese households' welfare. In this first simulation, we let the energy price fix and the deficit generated by the public utility producing electricity is absorbed by the government. Second, we investigate the consequences of increasing the price of energy in Senegal in order to maintain stable the balance sheet of the SENELEC (public utility producing energy). This simulation can also be interpreted as a CC policy implemented in Senegal. The last simulation is linked to a reduction in the agricultural productivity as direct effect of CC in Senegal ran

---

[11] We simulated the policies with other macroeconomic closures. The general trends of the results were maintained, although we observed some slight changes in results. A complete set of equations, variables, and parameters can be obtained from the authors.

[12] The poverty indexes of de Foster, Greer, and Thorbecke (1984) are additively decomposable; as such they are useful for this analysis because they allow us to measure not only the proportion of the poor among the population but also the depth and severity of poverty. For detailed information on this index family, see Ravallion (1994).

simultaneously with the second simulation. For this simulation we reduced the productivity of land by 10%. As agriculture is an important employer in the country, this is likely to have important distributional consequences in Senegal. The simulations performed are presented in Table 2.

Table 1 : Simulation performed in the CGE model

Identification of simulation	Description of simulation
Simulation 1	a 50% increase in world price of fossil fuels with fix electricity price
Simulation 2	a 50% increase in world price of fossil fuels with flexible electricity price
Simulation 3	Simulation 2 and a 10% loss of land productivity in agriculture

The distributional impact is done with the FGT poverty indices and the inequality changes are measure with the GINI coefficient. We present our result for the national level but we also decompose our analysis for three groups of the population. We subdivided our population in three groups, namely; the Dakar households, other urban households and the rural household. The results of our poverty analysis are presented in the four subsequent tables. Significant results are accompanied by *.

Table 2 : Poverty and inequality analysis for Senegal

		Poverty headcount (FGT0)	Depth of poverty (FGT1)	Severity of poverty (FGT2)	Inequality (Gini index)
Sénégal	**Référence**	0,6141	0,2738	0,1537	0,4825
	Sim 1A	0,6152	0,2742	0,1540	0,4824
	Δ %	*0,18%*	*0,16%**	*0,18%**	*-0,03%**
	Sim 2	0,6154	0,2744	0,1542	0,4824
	Δ %	*0,21%*	*0,23%**	*0,28%**	*-0,03%**
	Sim 3	0,6264	0,2827	0,1598	0,4854
	Δ %	*2,00%**	*3,27%**	*3,94%**	*0,58%**

Our first general comment for the national level is that the first two simulations produce the expected results insofar as the increases in world prices of fossil fuels and increase in price of electricity generate an increase in poverty. However, the impact is relatively small given the importance of the simulations performed. The first explanation for these results is that fossil fuels and electricity are not a major staple in the Senegalese households' consumption basket. In fact, it represents less than 3% of its total expenditure on goods and services. Hence, the households are not directly affected by these two price changes. The impact on household transits essentially through indirect effects such as changes in factor payments. As for the poverty changes, inequality is barely modified by the first two simulations although these changes are significant. We observe a very slight reduction in inequality. Given the small size of the changes, we could say that the simulations have little impact on inequality in Senegal. On the other hand, the reduction in land productivity has a stronger distributional impact. This is observed by an increase of the three poverty indices with the severity index increasing most by 3.94%. In this case, we also have an increase in inequality where the poorest households are found in the rural areas and this simulation touches them first. It is important to note that the reduction in land productivity is accompanied by a relatively strong increase in factor payment for land as it become relatively scares compared to labour and given the reduction in supply of agricultural goods on the market. Let us see how the national results compare to the regional decomposition. Results for Dakar are found in Table 3:

Table 3 : Poverty and inequality analysis for Dakar

		Poverty headcount (FGT0)	Depth of poverty (FGT1)	Severity of poverty (FGT2)	Inequality (Gini index)
Dakar	**Référence**	0,4970	0,2148	0,1201	0,4786
	Sim 1A	0,4981	0,2155	0,1206	0,4787
	Δ %	*0,23%*	*0,33%**	*0,41%**	*0,03%**
	Sim 2	0,4981	0,2158	0,1208	0,4788
	Δ %	*0,23%*	*0,46%**	*0,57%**	*0,04%**
	Sim 3	0,5068	0,2218	0,1256	0,4831
	Δ %	*1,97%**	*3,29%**	*4,56%**	*0,93%**

We note that for simulation 1 and 2, the increase in poverty headcount is not significant in Dakar but the depth and severity indices increase more compared to the ones at the national level. This is coherent with the fact that the Dakar households are the ones consuming the most fossil fuels and electricity. As opposed to the national inequality changes, we now have a small but significant increase in inequality in Dakar. For simulation 2, has a stronger negative impact in Dakar compared to national results and compared to simulation 1. We also reverse the sign of the Gini coefficient compared to the national level. For simulation 3, the negative results for poverty headcount is the same as the national level but the depth and severity indices decrease more. This can be explained by the fact that urban households don't benefit from the increase in factor payment of land but have to pay more for food staples since the supply has been reduced and market prices increased and reduction in wage related to rural workers migrating to urban labour markets. For this simulation we have a relatively strong effect on inequality which increases by almost 1% and is significant. These results show that indirect effect general equilibrium effects play an important role as the relatively strong negative impact in Dakar with the loss of land productivity[13].

Table 4 : Poverty and inequality analysis for Other Urban areas

		Poverty headcount (FGT0)	Depth of poverty (FGT1)	Severity of poverty (FGT2)	Inequality (Gini index)
Other urban areas	**Référence**	0,6589	0,2799	0,1510	0,4187
	Sim 1A	0,6595	0,2801	0,1512	0,4186
	Δ %	*0,09%*	*0,07%**	*0,12%**	*-0,03%**
	Sim 2	0,6595	0,2802	0,1513	0,4186
	Δ %	*0,09%*	*0,14%**	*0,20%**	*-0,03%**
	Sim 3	0,6695	0,2879	0,1565	0,4195
	Δ %	*1,61%**	*2,87%**	*3,62%**	*0,19%*

[13] Although we do not decompose groundnut in our model, this staple is an import input into the edible oil industries in Senegal and an important exported good either directly before being transformed or after transformation.

In other urban centres (OUC) the situation is somewhat different compared to Dakar for the first and second simulation. The headcount index increases but this change is insignificant. In the case of the depth and severity the increase in poverty are much smaller compared to Dakar and the national level. In the case of the Gini coefficient, is the same to what we observe at the national level. Finally, the impact of the third simulation are negative but weaker compared to the national and Dakar for all indices. As for the Gini coefficient, the variation is not significant. The results for the rural areas are presented in Table 5 below.

Table 5 : Poverty and inequality analysis for Rural areas

		Poverty headcount (FGT0)	Depth of poverty (FGT1)	Severity of poverty (FGT2)	Inequality (Gini index)
Rural areas	**Référence**	0,6265	0,2788	0,1596	0,4390
	Sim 1A	0,6285	0,2798	0,1602	0,4391
	Δ %	*0,31%*	*0,36%**	*0,40%**	*0,01%*
	Sim 2	0,6285	0,2802	0,1604	0,4391
	Δ %	*0,31%*	*0,48%**	*0,54%**	*0,02%*
	Sim 3	0,6333	0,2939	0,1700	0,4438
	Δ %	*1,07%*	*5,39%**	*6,55%**	*1,09%**

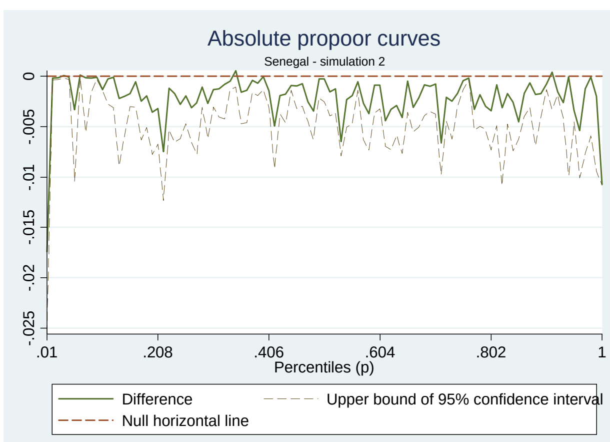
The results of the first simulation are quit interesting insofar as we have an increase in poverty depth and severity higher than the national level and quit similar Dakar. The general equilibrium effects are at play since these households consume little fossil fuels and electricity. Similar results are observed for simulation 2. The changes in inequality index are insignificant for the first two simulations. For the last simulation, the impact is strongly negative for all indices and above other regions and the national results albeit the headcount index change is not significant. The rural households are the clear losers of this CC impact and it could be quit dramatic for this group in Senegal if the materialize relatively quickly with little room for the population to adjust.

5. Pro-poor growth analysis

In what follows, the impact of the three simulations are described by the growth incidence curve (GIC) developed by Ravallion and Chen (2003). This curve shows the changes in real income by percentile of households before and after policy. We neither present all curves at the national level and for sub-groups but selected nor for all simulations but we present a few cases with specific features. To complete the pro-poor analysis, three indices have been computed: the pro-poor growth index (PPGI) of Kakwani and Pernia (2000), the poverty equivalent growth rate (PEGR) of Kakwani and Son (2003), and the absolute rate of pro-poor growth of Ravallion and Chen (2003) derived from the GIC[14].

We start with the simulation 2 at the national level. From Graph 1 below, we observe that no pro-poor or pro-rich trend is observed[15]. However, with the three pro-poor indices we have a pro-poor simulation with the three indices although, the only one significant is the Ravallion and Chen (2003) index. The results for the three pro-poor indices are presented in Table 7 of the appendix.

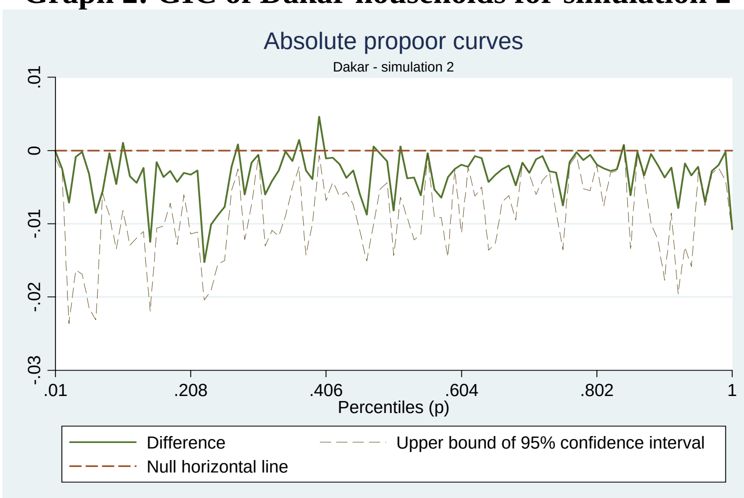
Graph 1: GIC of Senegal for simulation 2



[14] For a detailed presentation of these indices, see Boccanfuso and Ménard, 2008.
[15] A pro-poor trend is represented by a negatively sloped GIC and a pro-rich simulation by a positively sloped GIC.

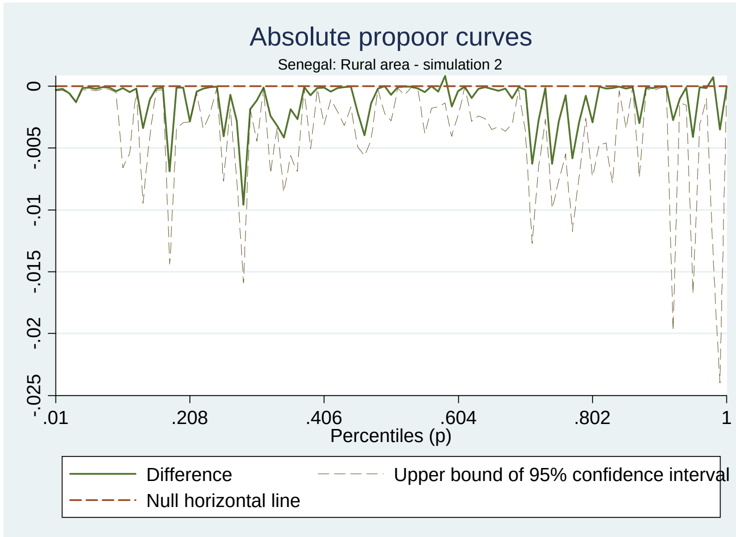
We note that the most negatively affected households are the poorest percentile and the richest one. We also see that the least affected households are between the second or third percentile up to the 15th and between the 35th and 40th. For Dakar, (Graph 2) we observe a similar situation with the most negatively affected found between the 10th and 25th percentile and the group of household between the 35th and 40th percentile seem to either benefit or have no or little negative impact. In this case, our pro-poor indices lead to conclude to a pro-rich recession for Dakar household for two indices but only one is significant.

Graph 2: GIC of Dakar households for simulation 2



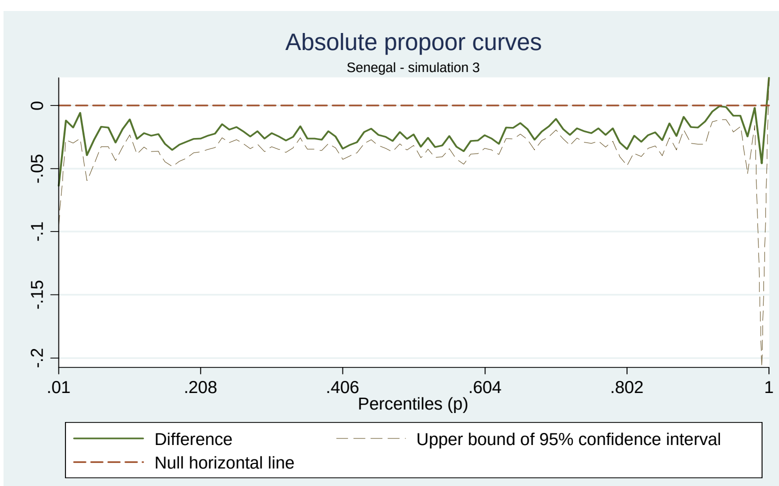
Finally for this simulation, we see little impact on the rural households (Graph 3) with the exception of two pockets of losers namely households between the 15th and 40th percentile and the ones between the 70th and 80th percentile. We observe practically no impact on the poorest 10% of households. The small impact from the GIC is confirmed by no significant results from our three pro-poor indices although the reduction in income seems to be pro-poor.

Graph 3: GIC of Rural households for simulation 2



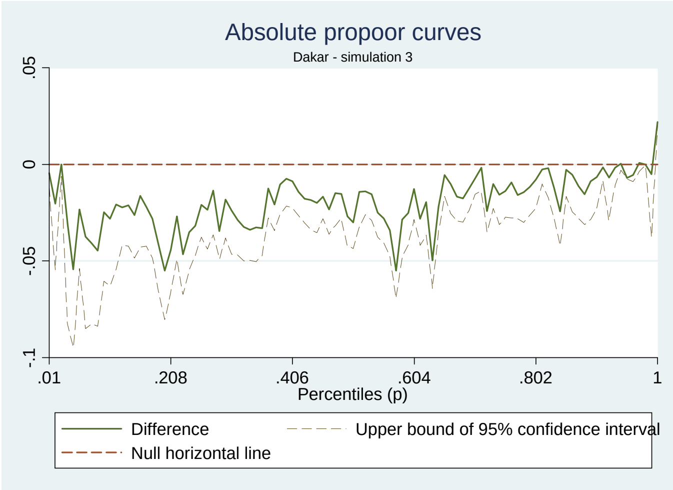
In the case of simulation 3, we see stronger effects and sloping trends on some of the GIC. At the national level (Graph 4), this trend is very slight but we see that the impact of the drop in land productivity is regressive or pro-rich. This results drawn from the GIC is confirmed by our indices. In fact, two provide pro-rich result but only one is significant. The third one is pro-poor but not significant.

Graph 4: GIC of Senegal for simulation 3



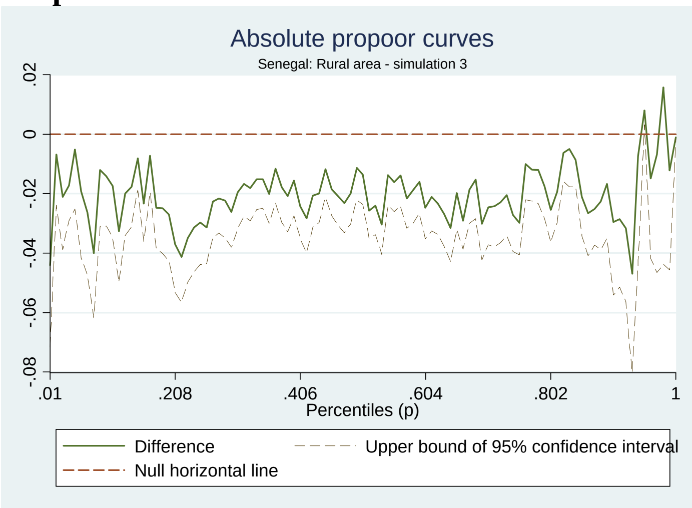
This trend is stronger when decomposing households groups. For the Dakar households (Graph 5), we clearly observe a pro-rich trend with a positive slope to our GIC computed where the richest households gain from the external shock. The first three percentiles are not strongly affected by the ones following up to the 40th percentile are the ones suffering the most from the simulation. As for the national level, the positive slope is confirmed by two indicators that suggest that the shock is pro-rich but none are significant.

Graph 5: GIC of Dakar households for simulation 3



For this simulation, the rural GIC (Graph 6) does not exhibit the same positive slope but we can see that winners are in the top 5 percentile where the biggest losers seem to be around the 20th percentile but with another negative peak around the 94th percentile. In this case, as for the Dakar households, two indices identify the simulation as being pro-rich and one pro-poor but none of the indices are significant.

Graph 6: GIC of Rural households for simulation 3



5. Conclusions

In this study we apply a macro-micro CGE to analyse possible consequences of mitigation policies in developed countries, and CC direct negative impact in a developing country, namely Senegal. As many authors have demonstrated, this methodology is the only one available that allows the analyst to link policy reforms, fiscal policies, world price changes to income distribution in a country. Some authors have used CGE models to analyse national mitigation policies but not with the macro-micro approach or not for developing countries. Our results show the importance of taking into account indirect general equilibrium effects as some groups who are not directly affected by a policy or external shock can experience strong negative general equilibrium effects as we found in our simulated reduction in land productivity for the Dakar households. The model also revealed relatively weak negative impact of increases in world price of fossil fuels as this good represents a small direct or indirect share of the consumption basket for poor households in the country. More importantly we show that maintaining electricity prices constant with a subsidy to the electric public utility provides little protection to the poor households since flexible prices generate poverty increases only slightly higher compared to the fix electricity price scenario.

In an extension to this paper we will investigate CC mitigating policies implemented at the national level and see how these policies affect poverty and income distribution but also the effect on wood charcoal consumption.

References

Araar, A., Y. Dissou and J.-Y. Duclos, (2008), “Household Incidence of Pollution Control Policies: a Robust Welfare Analysis Using General Equilibrium Effects”, Cahier de recherché du CIRPEE #08-09.

Armington P. S. (1969) « A Theory of Demand for Products Distinguished by Place of Production », *IMF Staff Paper*, nº 16, p. 159-176.

Bergman L., (1991), "General Equilibrium Effects of Environmental Policy: A CGE-Modeling Approach", *Environmental and Resource Economics* Vol. 1, pp 43--61.

Boccanfuso, D. Estache, A. and L. Savard, (2008a) Impact Analysis of Electricity reforms in Senegal: A Macro-micro analysis, *Journal of Development Studies*. Vol. 45, no 3 pp. 351-368.

Boccanfusso, D., A. Estache and L. Savard (2008b), "Incidence of environmental policies in Developing Countries: A survey", Cahier de recherche du GREDI, Université de Sherbrooke, #08-14.

Boccanfuso, D. Estache, A. and L. Savard, (2009) Impact Analysis of Electricity reforms in Mali: A Macro-micro analysis, *South African Journal of Economics*, Vol. 77, no 1 pp. 127-147.

Bourguignon F., Robilliard, A. S. and Robinson, S. (2005) Representative Versus Real Households in the Macroeconomic Modeling of Inequality. In T. J. Kehoe, T.N. Srinivasan, and J. Whalley (eds.), *Frontiers in Applied General Equilibrium Modeling*. Cambridge: Cambridge University Press.

Bourguignon, F. and Spadaro, A. (2007) Microsimulation as a Tool for Evaluating Redistribution Policies. *Journal of Economic Inequality*, Vol. 4, no. 1, pp. 77-106.

Bourguignon, F. and L. Savard (2008). A CGE Integrated Multi-Household Model with Segmented Labor Markets and unemployment in Bourguignon, F., L.A. Pereira Da Silva and M. Bussolo, eds. "The Impact of Macroeconomic Policies on Poverty and Income Distribution: Macro-Micro Evaluation Techniques and Tools" Palgrave-Macmillan Publishers Limited, Houndmills.

Chen, S. and Ravallion, M. (2004) Welfare Impacts of China's Accession to the World Trade Organization. *World Bank Economic Review*, Vol. 18, no. 1, pp. 29–57.

Cogneau, D. and Robilliard, A.S. (2000) Income Distribution, Poverty and Growth in Madagascar: Micro Simulations in a General Equilibrium Framework. IFPRI TMD Discussion Paper 61, International Food Policy Research Institute, Washington, DC.

Commission de Régulation du Secteur de l'Électricité du Sénégal (CRSE), (2003) Lettre de Politique de Developpement du secteur de l'Energie, Dakar Sénégal.

Decaluwé, B. Dumont, J.C. and Savard, L. (1999) How to Measure Poverty and Inequality in General Equilibrium Framework. Working Paper 9920, CREFA, University of Laval, Québec.

Dessus, S. and D. O'Connor (2003), Climate Policy without Tears: CGE-Based Ancillary Benefits Estimates for Chile, *Environmental and Resource Economics.* Vol. 25: pp. 287–317.

Direction de l'Environnement et des Établissements Classés (1999) « Stratégie nationale initiale de mise en oeuvre (SNMO) de la convention cadre des nations unies sur les changements climatiques (CCNUCC) », Ministère de l'Environnement et de la Protection de la Nature.

Doornbosch, R. and R. Steenblik, (2007), Biofuels: Is the Cure Worse than the Disease? Organisation for Economic Co-operation and Development, Round Table on Sustainable Development, Paris, France, September 11-12, p. 4.

Foster, J. Greer, J. and Thorbecke, E. (1984) A Class of Decomposable Poverty Measures. *Econometrica* Vol. 52, no. 3, pp. 761–766.

Fullerton, D. and G. Heutel, (2007) The General Equilibrium Incidence of Environmental Taxes, *Journal of Public Economics* Vol. 91, no. 3-4, pp. 571–591.

Gørtz, M. Harrison, G. Neilsen, C. and Rutherford, T. (2000) Welfare gains of extending opening hours in Denmark. Economic working paper B0003, University of South Carolina, Darla Moore School of Business, Columbia, South Carolina.

Hertel, T. and Reimer, J. (2005) Predicting the poverty impacts of trade reform, *Journal of International Trade & Economic Development*, Vol. 14, no. 4, pp. 377-405.

Huppi, M. and Ravallion, M. (1991) The Sectoral Structure of Poverty During an Adjustment Period: Evidence for Indonesia in the Mid1980s. *World Development*, Vol. 19, no. 2, pp. 1653–1678.

Kakwani, N. and E. Pernia, (2000), "What is Pro-Poor Growth?", *Asian Development Review* Vol 18, no. 1, pp. 1-16.

Kakwani, N. and H. Son (2003), "Pro-Poor Growth: Concept, Measurement with Country Case Studies", *The Pakistan Development Review*, Vol 42, no. 4, pp. 417-444.

King, D. and Handa S. (2003) The welfare effects of balance of payments reforms: A macro-micro simulation of the cost of rent-seeking.? *The Journal of Development Studies*, Vol. 39, no. 3, pp. 101-128.

Ministère de l'environnement du Sénégal (2006), Plan d'action national pour l'adaptation aux changements climatiques, Dakar Sénégal.

Mongabay, (2009), http://rainforests.mongabay.com/deforestation/2000/Senegal.htm.

O'Ryan, R., S. Miller, and C.J. De Miguel, (2003), A CGE framework to evaluate policy options for reducing air pollution emissions in Chile, *Environmental and Development Economics.* Vol. 8: no. 2. pp. 285–309.

Oxfam (2007), Bio-Fuelling Poverty: Why the EU renewable-fuel target may be disastrous for poor people, Oxfam briefing notes.

Ravallion, M. and S. Chen (2003). "Measuring Pro-Poor Growth", *Economic Letters*, Vol. 78 no. 1, pp. 93-99.

Ravallion, M. (1994) *Poverty Comparisons*, Reading, Harwood Academic Publisher.

Savard, L. (2005) Poverty and Inequality Analysis within a CGE Framework: A Comparative Analysis of the Representative Agent and Microsimulation Approaches. *Development Policy Review*, Vol. 23, no. 3., pp. 313–332.

Timilsina, G. R., (2007). "Atmospheric stabilization of CO2 emissions : near-term reductions and intensity-based targets," Policy Research Working Paper Series 4352, The World Bank

Von Braun, J. (2007), The World Food Situation: New Driving Forces and Required Actions, IFPRI, Food Policy Report No. 18, Washington, D.C.

Vos R, and De Jong N. (2003) Trade liberalization and poverty in Ecuador: a CGE macro-microsimulation analysis. *Economic System Analysis*, Vol. 15, no. 2, pp. 211-232.

Winters, P, R. Murgai, E. Sadoulet, A. de Janvry, and G. Frisvold (1998), Economic and Welfare Impacts of Climate Change on Developing Countries, *Environmental and Resource Economics* Vol. 12, no. 1, pp. 1–24.

Appendix

Table 7 : Pro-poor growth indices

		SENEGAL			
		Country	**Dakar**	**Other urban centers**	**Rural area**
Sim 1	Growth rate of incomes, g	–	–	–	–
	Ravallion & Chen (2003)	*Pro-poor recession*	Pro-rich recession	Pro-rich recession	Pro-poor recession
	Kakwani & Son (2003)	Pro-rich recession	Pro-poor recession	Pro-poor recession	Pro-poor recession
	Kakwani & Pernia (2000)	Pro-poor recession	Pro-poor recession	Pro-rich recession	Non strictly pro-poor recession
Sim 2	Growth rate of incomes, g	–	–	–	–
	Ravallion & Chen (2003)	*Pro-poor recession*	*Pro-rich recession*	Pro-rich recession	Pro-poor recession
	Kakwani & Son (2003)	Pro-poor recession	Pro-rich recession	Pro-rich recession	Pro-poor recession
	Kakwani & Pernia (2000)	Non strictly pro-poor recession	Pro-poor recession	Pro-poor recession	Non strictly pro-poor recession
Sim 3	Growth rate of incomes, g	–	–	–	–
	Ravallion & Chen (2003)	*Pro-rich recession*	Pro-rich recession	*Pro-rich recession*	Pro-rich recession
	Kakwani & Son (2003)	Pro-rich recession	Pro-rich recession	Pro-poor recession	Pro-rich recession
	Kakwani & Pernia (2000)	Pro-poor recession	Pro-poor recession	Non strictly pro-poor recession	Pro-poor recession

* Results computed by the authors. Significant results at the 5% rejection level are presented in italic character in the table