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Bioenergy trade, a theoretical analysis

Though the potential of bioenergy in the mitigation of greenhouse gases (GHG) coming from fossil energies is strongly debated, several developed countries such as the United States, the European Union and Japan have for several years already outlined ambitious objectives of incorporating bioenergy into their energy package in order to reduce their GHG emissions, notably in the field of transportation. Bioenergies are presented as an alternative to fossil fuels that is both renewable and relatively clean. The policies implemented give rise to little in the way of imports and yet, for biofuels to reach a 10% share of fuel consumption in transports, the United States, Canada and the EU would need to use 30%, 36% and 72% of their farm lands respectively (Von Lampe, 2006). A very simplified theoretical model of the world economy shows that opening up Bioenergy to trade would result in an increase in GHG emissions if Southern countries have a comparative advantage in the industrial sector, or conversely, a reduction thanks to bioenergy imports if Northern countries have the best performing industrial sector.

The development of bioenergies has contrasting effects on GHG emissions

Although the use of bioenergies may be considered as neutral as regards GHG emissions, their production requires the use of fertilizers and chemical products whose manufacture has a non-null impact in terms of GHG, at least in the developed countries. In Southern countries, ethanol production from sugar cane in Brazil or biodiesel from palm oil in Indonesia and Malaysia use less chemical inputs. On the other hand, the development of bioenergies in the Southern countries, favoured by a much lower energy cost than in the North, requires a change in land-use for agriculture, generating major GHG emissions (Fargione et al., 2008; Searchinger et al., 2008).

The impact due to the change in land-use is difficult to assess because it depends on the quality of the soils and their previous use, factors which determine the quantity of sequestrated carbon in soil and biomass (Schneider and Smith, 2009). On the one hand, the change in land-use releases the sequestrated carbon in soil and biomass; on the other hand, the sequestration capacity of the soils of cultivated land is reduced in relation to meadows and forests. According to Birdsey (1992), the average level of carbon sequestration in the soils of cultivated lands is 11 tons per hectare, while it is of 14 t per hectare for pastures and 57 t per hectare for forests.

In its 2007 report, the International Panel on Climate Change assesses the share of GHG emissions due to the change in soil use and the forestry industry at 17% of the total (see graph 1). This is the balance between raw carbon emissions and carbon absorption resulting from the clearance or dereliction of cultivated lands dedicated to crops or pasture and wood gathering (industrial use and heating wood). The biggest source of emissions comes from deforestation for conversion into farmlands, notably in Indonesia and Brazil, while industrialized countries have a negative balance.

However, as the phenomena of emission and absorption of CO2 in the biosphere depend on complex interactions, the assessments on emissions coming

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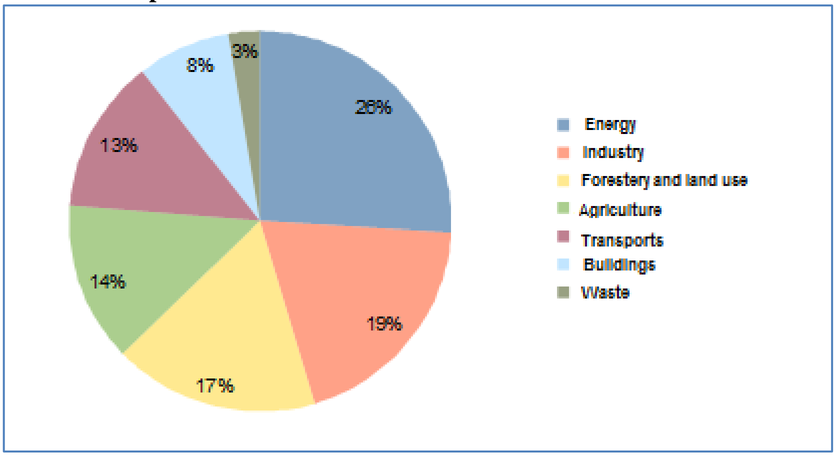
from the change in land use are very different according to studies. The assessments of the effects attributable solely to bioenergies are all the more difficult (see De Cara et al., 2012, for a summary on these works).

Graph 1: Sectoral shares of the world's GHG emissions



Source: Contribution of Working Group III to the Fourth assessment Report of the Intergovernmental Panel on Climate Change, 2007. B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds), Cambridge University Press.

In a context of rising agricultural production, the continuation of policies to replace fossil-energies by bioenergies raises major questions about the effects that the development of trade in bioenergies may have. While bioenergies enable the reduction of GHG emissions from industry and transport by reducing the consumption of fossil fuels in those sectors, they may increase the level of GHG emissions due to the change in land-use that the development of their production may generate. The global impact will also depend on the environmental policies adopted by the States, and this depends on their level of wealth and development.

Frame: Models of North-South trade and environment

Many theoretical works have integrated environmental problems into the economic theory of international trade. The book of Brian Copeland and Scott Taylor (2003) presents the global North-South approaches which, notably, address the problems of "pollution havens" emerging in Southern countries and "carbon leaks" generated by stricter regulations in Northern countries. The canonical approach to the model developed here is a reformulation of the Hecker-Ohlin-Samuelson (HOS) model with two regions (North and South), two production factors, (work and capital) and an induced product: pollution. Both regions stand out by their endowment factors, Northern economies being more richly endowed (and so wealthier) than Southern economies. The prices of factors are fixed on the domestic markets of each country. The levels of pollution and environmental taxes are fixed by local regulators, assumed to be benevolent and efficient, without international coordination. Free-trade impacts are assessed in relation to an autarkic situation. Situations of partial openings to trade are permitted thanks to the introduction of frictions. The HOS model assumes a large number of agents in each country, and in particular, a large number of firms in all sectors.

Using the North-South trade model (see frame), we examine the potential impacts of a development of the bioenergy trade, but with the emphasis on the GHG emissions which result from this development at world level. We determine the trade balance of a world economy composed of several countries belonging to both regions, North and South, contributing to GHG emissions and developing non-concerted environmental policies, that is to say without international coordination. The two regions are only distinguished by their endowment in effective labour (which varies according to the human capital of workers), higher in the economies of the North than those of the South. This leads to more demanding environmental policies in the North than in the South. Each economy is composed of two sectors, agriculture and industry, which emit GHG. The agricultural sector produces both a final consumption good and an intermediate product: bioenergy. One of the main assumptions of this analysis resides in the relationship between expansion of agriculture (change in land-use) and GHG emissions: conversely to fossil energies (only used in the industry to simplify the analysis), the GHG emissions of which may be supposed to be proportional to consumption, soils have various differentiated effects on GHG because of a varying carbon sequestration capacity. So, though over the long term farmlands are likely to stock a part of the carbon released at the time of their change, they have a lesser sequestration capacity compared with their initial state. With the expansion of farmlands, these variations in sequestration capacities correspond to net emissions of GHG which will be higher for old forests than for old pastures. To express this non-linearity of GHG emissions with the land converted to agriculture, we assume a convex relationship between cultivated areas and net emissions of GHG. These emissions increase more and more rapidly with the volume of cultivated areas and we assume that this relationship is identical for all countries (which are "given" distributions of lands with similar characteristics), in order to isolate the effects that are only due to the international bioenergy trade, without introducing a prejudicial asymmetry in North-South trade.

Free-trade equilibrium, comparative advantages and pollution

The first result from this model is that at free-trade equilibrium, the wealthier Northern countries, which charge higher environmental taxes, may nevertheless have a comparative advantage in the industrial sector, the sector which is at the origin of a greater intensity of GHG emissions per work unit. If bioenergies are easily substitutable for fossil fuels and if GHG emissions due to the change in land-use increase sharply with the expansion of agriculture, then the North is likely to have a comparative advantage in industry. According to the assumptions made in terms of production (substitutability between energies and labour in industry, between labour and cultivated lands) and convexity of the function of GHG emissions, Northern countries may be net exporters of industrial goods.

This overturns one of the results usually accepted in the literature on international trade, that is to say that Southern countries attract polluting activities thanks to their more lax environmental regulation, and form what is called "pollution havens".

The second result is that international trade may increase or reduce the world level of GHG emissions according to the region which has a comparative advantage in the industrial sector. This is due to the fact that environmental taxes are always lower in the least wealthy countries (South) than in the wealthy countries (North). After an opening up to trade, this dissymmetry of environmental policies implies that regional emissions of GHG always vary more sharply in the South than in the North. So while the South has a comparative advantage in industry, the increase in GHG emissions due to industrial development in the South is larger than the drop in industrial emissions in the North. International trade increases world emissions of GHG. If, conversely, the North has a comparative advantage in industry, the reduction in Southern emissions is higher than the increase in Northern emissions, and so trade brings a reduction in world GHG emissions compared with the autarky where all countries emit the same quantity of GHG.

The model was specified in such a way that, in autarky, the emissions from all countries are levelled. However, higher emission intensities in the South than in the North per unit of work correspond to the same level of emissions in the North and South, because of supposed variations in the endowments in human capital. The opening-up to trade induces varied reactions from countries according to the regions to which they belong, which depend on their respective and comparative advantages. On the assumption of a more industrialized North than South, Northern emissions increase compared with their autarky level, while Southern emissions diminish. A dissymmetry is added to this variation in behaviours due to comparative advantages between the two regions in the scale of their reactions.

The variation in behaviour is not due to Southern governments being less aware of their citizens' welfare than Northern ones, but simply to the fact that countries set their environmental taxes according to their own interests, without international dialogue which would encourage them to take into account the impacts of their policies on other countries. In the absence of international coordination, environmental policies are the result of a Nash equilibrium where each government considers as a given the emissions of the other countries. Northern countries being better endowed in human capital (this is the sole difference between the regions), they are wealthier than Southern countries irrespective of the trade constraints which may exist between countries. Since environmental quality is a normal good (the demand for which increases with wealth), Northern environmental taxes are always higher than Southern ones.

Conversely to the classical result of the theory of International trade, that is to say the theorem of the relative balanced Factor-Price-Equalization of free-trade, factor price ratios (salary over tax) are variable from one region to the next in free-trade because of the non-linearity of agricultural GHG emissions. As a consequence, if the North has a comparative advantage in industry, industrial production develops in the North where higher environmental taxes ultimately lead to less global pollution. This effect offsets the increase in emissions coming from agricultural expansion taking place in the South. In the opposite case where the South would become a net exporter of industrial products, environmental quality would deteriorate at world level.

Three forces at work in the increase in pollution levels

In order to better identify the forces which have an influence on the pollution levels of the North and South, it is possible to break down the impact of trade on pollution in each region into composition effect, technique effect and scale effect (see Ollivier, 2010).

The scale effect reflects the increase in pollution due to the increase in activity which results from international trade.
The composition effect measures the relative share of each type of goods produced in the global production of a country. It reflects the direction of trades according to the comparative advantage of each region. The composition effect is positive for the region which has a comparative advantage in industry and negative for the other, since industry is the most pollution intensive sector. The technique effect measures the variation in intensity of pollution in production. It depends on factor prices and more specifically on the development of environmental regulations at the time of free trade. If regulation becomes stricter in a country, then the marginal cost of pollution rises, thereby inducing a negative technique effect. So this effect takes into account the countries' response to free-trade through the adjustment of their environmental policies.

Table 1 illustrates this breakdown of trade effects on the regional levels of GHG emissions in both cases, namely the case of the South having a comparative advantage in industry and where world emissions increase with trade and, conversely, the case of North having a comparative advantage in industry and where global emissions decrease.

In both cases, the scale effect leads to an increase in GHG emissions for countries having a comparative advantage in industry and a decrease for the more agricultural countries. This may seem surprising since opening up to trade generates greater wealth from the countries, and so world demand for agricultural and industrial goods increases. However, the scale effects for countries indicated in the table are weighted by the variations in the relative wealth of the countries, which falls for the agricultural countries while they increase for the industrial countries, hence the opposed signs. Finally, there are scale and composition effects which are added together. On the other hand, since environmental tax (usually) increases in a country with a comparative advantage in industry, the technique effect is negative. This is always the case of a Southern country, but it depends on the relative abundance of the workforce for a Northern country (hence the condition $L>Lm$ indicated in the table): when effective labour is relatively rare in the South, the demand from the Northern countries as regards bioenergy may not be met, given the tax level of the autarky, and this may induce a fall in environmental tax in free trade. We show that trade impacts on the regional levels of emissions are mainly caused by the changes in scale and composition of economies. The influence of the change of environmental regulation is secondary.

Table 1: Impacts of trade on each regional level of GHG emissions.

	Scale effect	Composition effect	Technical effect	Total effect
If comparative advantage of South in industry				
North	+	+	- if and only if $L>Lm$	+
South	-	-	+	-
If comparative advantage of North in industry				
North	-	-	+ if and only if $L>Lm$	-
South	+	+	-	+

Note: ssi $L>Lm$ means that the condition is fulfilled if and only if the quantity of workforce in free trade is higher than a threshold level.

The result whereby the North may have a comparative advantage in the relatively most polluting sector while comparative advantages are fixed by the variations in the environmental regulations is interesting because it validates the empirical observations (Antweiler et al, 2001) without it being necessary to invoke the fact that the Northern countries have a more qualified workforce and more capital than the Southern countries to explain the absence of the empirical observation of the "pollution haven". The fact that all production sectors generate GHG emissions, but in different quantities and according to a specific relationship at production level, is enough to explain this result as soon as the environmental policies are adapted to each sector and develop with the opening up to international trade.

Conclusion

This research, which relies on a very simplified model of the world economy to analyse the consequences of the bioenergy trade, nonetheless raises questions about the policies for support to bioenergies developed by the Northern countries. In particular, besides all the redistributive considerations which would lead the States to favour local farmers, nothing seems to justify bioenergies consumed by Northern countries being locally produced. Of course, we need to ascertain that the replacement of fossil energies by bioenergies has a real positive environmental impact as regards emission reduction. In our model, the assumptions made about GHG emissions due to changes in land-use are too limitative, particularly the symmetry between countries (within the same region and between regions). Giving detailed consideration to the non-linearities of the emissions according to lands and regions is the challenge of the simulation models. The environmental assessment of bioenergy production in Southern countries may not be a justification for production support policies in the Northern countries. The absence of international coordination of environmental policies is probably the first problem to be resolved by the international community. For instance, rather than limit all imports of bioenergy from Brazil and Indonesia, it seems more effective to develop concerted, focused policies against deforestation, such as international transfer mechanisms for the Reduction of Emissions linked to Deforestation and Deterioration (REDD), or implement to certification systems for industries.

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