MATISSE

WORKING PAPERS

29

5/2008

BIOFUELS AND THE ENVIRONMENT-DEVELOPMENT GORDIAN KNOT: INSIGHTS ON THE BRAZILIAN EXCEPTION

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MATISSE Methods and Tools for Integrated Sustainability Assessment

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MATISSE (Methods and Tools for Integrated Sustainability Assessment) aims to achieve a step-wise advance in the science and application of Integrated Sustainability Assessment (ISA) of EU policies. In order to reach this objective the core activity of the MATISSE project is to improve the tools available for conducting Integrated Sustainability Assessments.
Project duration: April 1st, 2005 - March 31st, 2008
MATISSE is supported by the 6th Framework Programme of the European Union.
Contract number: 004059 (GOCE) - MATISSE

Preface

About the MATISSE project

The MATISSE (Methods and Tools for Integrated Sustainability Assessment) project is funded by the European Commission, DG Research, within the 6th Framework Programme. The project is interested in the role that Integrated Sustainability Assessment (ISA) could play in the process of developing and implementing policies capable of addressing persistent problems of unsustainable development and supporting transitions to a more sustainable future in Europe. The core activity of MATISSE is to develop, test and demonstrate new and improved methods and tools for conducting ISA.

This work is carried out through developing and applying a conceptual framework for ISA, looking at the linkages to other sustainability assessment processes, linking existing tools to make them more useable for ISA, developing new tools to address transitions to sustainable development and applying the new and improved tools within an ISA process through a series of case studies.

The extent to which the case studies are carrying out a complete ISA for their area of focus varies between attempts to cover all phases of an ISA process to partial implementation of the process. Equally, different case studies are oriented to developing and testing tools and approaches to some, but not all, of the methodological challenges of ISA. The case studies are complementary, however, and the set of cases offers the opportunity to address a wide range of methodological challenges and to explore linkages between cases. An evaluation of practical experiences with ISA implementation in the case studies will provide guidance on the further improvement of methods and tools. Results will also contribute to more informed policy advice.

What is ISA?

Within the MATISSE project, Integrated Sustainability Assessment (ISA) has been defined as a cyclical, participatory process of scoping, envisioning, experimenting, and learning through which a shared interpretation of sustainability for a specific context is developed and applied in an integrated manner, in order to explore solutions to persistent problems of unsustainable development. ISA is conceptualised as a complement to other forms of sustainability assessment, such as Sustainability Impact Assessment, Integrated Assessment and Regulatory Impact Assessment. Whereas these other forms of assessment fulfil the pragmatic need for *ex ante* screening of incremental sectoral policies that are developed within the prevailing policy regime, ISA is conceptualised as a support to longer-term and more strategic policy processes, where the objective is to explore persistent problems of unsustainable development that have a systemic pathology and possible solutions to these. ISA is therefore oriented toward supporting the development of cross-sectoral policies that specifically address sustainable development and at exploring enabling policy regimes and institutional arrangements.

MATISSE Working Papers

Matisse Working Papers are interim reports of project activities that are published in order to illustrate ongoing work and some provisional conclusions, as well as providing the opportunity for discussion of the approaches taken by the project and interim results. This discussion should be both within the project and between project members and the broader scientific and policy communities. Readers are encouraged to contact the authors to discuss the content of MATISSE Working Papers.

Jill Jäger and Paul Weaver

Editors of the MATISSE Working Paper Series

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BIOFUELS AND THE ENVIRONMENT-DEVELOPMENT GORDIAN KNOT: INSIGHTS ON THE BRAZILIAN EXCEPTION

1. Introduction

Brazil is an agricultural giant that is in the process of becoming an energy giant as a biofuel exporter. Most OECD countries have expressed interest in Brazilian biofuels for coping both with the supply security and the climate risk. None of them has enough biofuel potential domestically. The prospect of a high oil export price provides a unique opportunity for Brazil to design a huge program of biofuel production and export (especially of ethanol) as a development boost and as a component of negotiating and implementing international climate accords. Brazil owns a unique stock of unused croppable land that could be harnessed for a huge biofuel export to the rest of the world. But part of it is also the largest forest in the world, with a huge potential for wood and other forest products, plus a natural carbon storage and a biodiversity wealth, not to forget the local climate equilibrium. Therefore Brazil is facing crucial choices on exploiting its biomass potential without losing so many positive externalities.

This paper first puts into perspective the current Brazilian energy context and its implications for the strategy of this country in climate negotiations. Second it presents a numerical experiment aiming at disentangling the numerous impacts of large-scale exports of ethanol up to 2030 in the context of a world commitment to stabilize greenhouse gas (GHG) emissions at 450 ppm of CO_2. Third there is an examination of the interplay between mechanisms that determine the impact of a large-scale development of the Brazilian biomass on the prices of food and pressure on forest in Brazil and how Brazil might pursue a dual aim of environment and development. Brazil's emissions are dominated by the deforestation component, while the political expectations consist mainly in developing more rapidly and with a less unequal pattern.

2. Climate-energy-development: the specifics of the Brazilian context

2.1. Biomass energy and the new energy deal in Brazil

Renewable energies (hydroelectricity and ethanol) make Brazil unique as a low GHG-emitter due to energy. Furthermore, it is in the process of strengthening its offshore oil production capacity and reversing its foreign exchange payment for energy. However this success story might not be enough to cope with future growth of demand for energy and fuels. Since the 1975 ProAlcool plan up to 2005, Brazil has been the biggest ethanol producer and the cane-to-ethanol route remains the most efficient; well ahead of the US corn-to-ethanol route. Brazil exported 20% of its total production of 17.5 billion liters in 2006-07. The local ethanol use represented 50% of the volume and 35% of the useful energy in the automotive fuel consumed in Brazil. In total 14% of the national total primary energy demand is derived as a fuel from ethanol or as heat and electricity from the bagasse burnt in the cane-processing plants.

In 1975 the ProAlcool plan was backed by a vast array of measures: administered price, subsidies, public loans, private loans with a public guarantee. Between 1997 and 1999 prices were liberalized. There is no more direct financial aid but only tax exemptions in the public budget. The government still regulates the ethanol rate in the fuel: 25% before May 2006, then 20% due to a high sugar price, and 23% since November 2006. The World Resources Institute has calculated that Brazil has produced 230 billion liters of ethanol, saving 52 billion (in 2003 US$)[1] on oil imports and reducing CO_2 emissions by about 574 Mt since 1975 – that is about 10% of the country's emissions. However the cumulative data do not account for the fluctuations in the plan. While in the mid-80s about three

[1] According to Goldemberg and al. (2003) quoted by Coelho (2005).

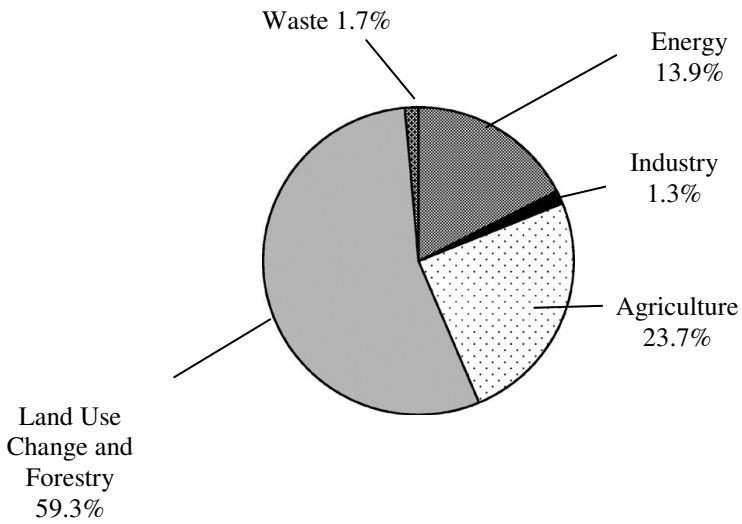
quarters of the cars were using ethanol, the high sugar price in 1989 caused a big enough reduction of ethanol demand for consumers' confidence in a discredited ProAlcool plan to decline. In 2003, the market innovation of the flex-fuel cars opened a new area as the proportion of ethanol can go from 25% of gasohol upwards. In 2006, the flex-fuel share represented 78% of the 1.1 million car sales and the stock was 2 out of 22 million (ANFAVEA, 2007). Most of the 32 000 gas stations in Brazil sell anhydrous ethanol (USDA, 2006). The flexibility of the technology allows for consumers to be protected against the risk of sugar and oil price fluctuations. In 2004, the government has revisited its biodiesel program as part of a "green" strategy. The legal share of 2% (in volume) is expected to be compulsory in 2008 and to increase it to 5% in 2013. However its high price remains an obstacle[2].

The ethanol success story is partly due to Brazil's favorable agricultural conditions, conducive to low production costs (climate, land and labour). Private investors have brought capital, R&D, technical progress and growth. But this pattern may not be reproducible for biodiesel, which relies on numerous small producers, or even for an expanded ethanol program except if the state invests. Despite the high and sustained ethanol plan, Brazil has always maintained a high effort towards becoming self-sufficient in oil by 2006, on the basis of the state-controlled company Petrobras. In 2007, the domestic demand is nearly at the level of domestic production at 1.9 million barrels a day. Since November 2007, a famous offshore oil discovery at Tupi promises 5 to 8 billion barrels of high quality oil (approximately 40% of current reserves) plus associated gas. Brazil reserves would thus be between those of Venezuela and Nigeria. Brazil's inherited low carbon energy mix is bound to mean a high marginal abatment cost curve in the future, except in the area of forest, land use and biomass derived GHG.

3. Brazil stakes in the climate change negotiation

Brazil is unique as a large country whose emissions are not dominated by fossil fuel sources. In Brazil more than 80% of GHG are emitted by agriculture or land-use change and forestry (LULUCF).

Figure 1. Distribution of GHGs across sectors in Brazil



Source: 2000 database CAIT (www.cait.wri.org).

This poses a specific problem, since the Kyoto framework poorly addresses deforestation the intensification of which could offset the abatements yielded by a full implementation of the Kyoto Protocol. Brazil has kept referring to the Rio Convention principle of "a common but differentiated responsibility". Brazil signed the Kyoto Protocol first and it aimed to stick to a pro-active vision likely

[2] The biodiesel program is thus a major area CDM projects with Annex 1 countries.

to be endorsed by the G77 or at least by a large number of developing countries. In 2005, the Brazilian President stressed that the parties to the Climate Convention should understand that Brazil could not sacrifice its employment and its rate of economic growth on the pretext of protecting climate as a public good and its own natural capital, while the lack of financial capital is a main bottleneck for its growth potential (NAE: Nucleo de Assuntos Estrategicos da Presidencia da Republica)[3].

Within these overall strategic principles shared by all the developing countries, the specific position of Brazil regarding its participation in an international agreement on climate change has two components:

- deforestation, which Brazil recently accepted to be measured and part of GHG control;
- the potential of ethanol to limit GHG emissions and to improve world energy security through large exports of biofuels over the short and middle term, without waiting for the second generation of bioenergy.

3.1. Deforestation control : a sensitive dimension of any climate regime

While deforestation in Brazil was estimated at 2.6 Mha/year from 1990 to 2000, it accelerated to 3.1 Mha/year during 2000-2005. Brazil is one of the largest potential carbon sinks in the Land Use, Land-Use Change and Forestry (LULUCF) sector. According to the Stern report (2006), the Afforestation/Reforestation (A/R) has a truly low-cost emission-reduction potential in the range of 1 to 5 US$/t CO_2 avoided. This is a priority potential that was discussed with non Annex I Parties at the 13th climate conference in Bali (December 2007). However the modalities under which a cap and trade system can draw perennial financial flows significant enough to control deforestation are far from being clear and cannot be easily extrapolated from the experience in other sectors.

First, measurement uncertainties in GHG deforestation potentials hinder the necessary agreement on baselines and on the reality of the slowdown of deforestation. Technical and scientific measurement methods have not yet been agreed on. It is even still debated whether Amazonian tropical forest is a GHG sink or a source. Biomass quantities are assessed by satellite images combined with field measures. The range of values varies considerably. Reis (1992) indicated a range of 270 to 400 t/ha for wood content in Amazonia with a conventional 50% carbon content. IPCC (2001) adopted a lower average value of 120 tC/ha for tropical forests. Of course the diversity of ecosystems makes it all the more complex. The Brazilian States of Mato Grosso, Para and Rondônia, have mixed forest-savannah ecosystems with a lower density of 70 tC/ha. Solving such measurement uncertainties is an obvious prerequisite to any LULUCF agreement.

Beyond the difficulty of measuring the carbon balance of forests for a benchmark year, the complexity of deforestation dynamics is an additional obstacle to defining a reference scenario from which avoided emission could be calculated. The displacement of the agricultural frontier is indeed driven by a mix of factors hard to predict in advance and from which a large spectrum of baseline deforestation rates can be derived. The multiple factors which have a bearing on the displacement of the agricultural frontier are: the price of agricultural products; technological change; access to credit or the interest rate on borrowing; wage rates for agricultural labour; transport costs; infrastructure; and, property rights policy. It can be assumed also that the negotiation itself can have a perverse effect, if a country chooses to accelerate deforestation before the agreement fixes a starting year. Lastly, there is the problem of the anthropocentric origin and of the additionality of efforts to protect the forest, while the cost of thes efforts depends on the opportunity cost of land use, a factor depending on the country or region context.

Controlling deforestation requires complex modalities (fitted to each national or regional context) and a perennial financial flow, if the control is to be sustainable. One question is whether LULUCF should be linked to carbon markets in the electricity sector and industry; it might increase the risk of volatility of the carbon price, with a specific risk of plunging to artificially low values. Furthermore the tropical forest produces externalities on biodiversity, on local climate apart from the global climate risk. Therefore, even though some incentives to stop deforestation can be found using carbon prices, it is

[3] cite par Texeira, 2006

not obvious that this carbon price should necessarily appear in a market including LULUCF and other emissions and it is sure that other types of domestic and international incentives have to be found in addition to carbon prices. The difficulty is that these incentives have to be targeted to reform deep features of the Brazilian society including land property rights and the informal economy.

3.2. World-scale ethanol export program as a Brazilian climate contribution

The cost efficiency of Brazilian ethanol production and Brazil's comparative advantage in bioenergy are well-established facts, as documented in Table 1. This comparative advantage relies basically on the natural characteristics of Brazil, including its climate. But it relies also on a unique and long-standing learning-by-doing process. For example, the high level of recycling of byproducts in the production process has played a central role in lowering the ethanol production cost in Brazil (Goldemberg et al., 2003).

Country	**Anhydrous ethanol cost production**		**Raw material**
	US$/liter(1)	US$/liter(2)	
Brazil	-	0.20	sugar-cane
Center-South	0.15		sugar-cane
North-Northeast	0.18		sugar-cane
USA	0.33	0.47	Corn
Europe	0.55	0.97	beet, wheat
Thailand		0.29	sugar-cane
Australia		0.32	sugar-cane

Table 1. Ethanol cost comparisons in- and outside Brazil

Source: (1) Governor`s Ethanol Coalition/UNICAMP; (2) Datagro. Note: US$ 1 = R$ 2.5 (average currency exchange rate of 2005). Source: UNICAMP (2005)

Brazil exports ethanol to the USA, India, Venezuela, Nigeria, China, South Korea and the EU. The total ethanol export to the USA amounts to 64% of the total ethanol export. 1.77 billion liters are submitted to a duty cost, while an additional 0.475 billion liters are exported through the indirect channel of the Caribbean Basin Initiative, CBI. In 2006 Japan negotiated an export potential to allow a 3% share of ethanol in the gasoline and the EU has also declared a strong interest. Petrobras has embarked on a long-run scheme of investment including the building of a pipeline from the ethanol-producing areas to the harbours. It anticipated to raise its ethanol exports by 320 million liters in 2006 and by 850 million liters in 2007. The target is to export 3.5 billion liters per year around 204. However, although there is a well-documented technical report by the Unicamp University, there is no study so far of the overall economic implication of such a scheme for Brazil and for any ambitious climate policy of the international community.

[4] Kojima (2007)

4. Biofuels as a key incentive for Brazil to adhere to a 450 ppm Kyoto-type coalition

Notwithstanding pending controversies about the net carbon benefit of producing energy through biomass (this net benefit is certain in the Brazilian case), we take it for granted that Brazil can significantly contribute to combating climate change by delivering large exports of ethanol. This section assesses what difference a huge ethanol export scheme could make for Brazilian development performance in a world where a regime constrains GHG to 450 ppm CO2-eq.

This assessment was conducted within the MATISSE project using a new modeling tool, an architecture consisting of the coupling of a dynamic general equilibrium model, Imaclim-R, with a land-use model (Nexus Land-Use) and a model of agricultural activities (Agripole). As explained in the working paper presenting *A novel hybrid architecture for agriculture and land use in an integrated modeling framework* (MATISSE WP 27), the main specificities of IMACLIM consist of combining: a) hybrid modelling in value and in physical quantities; and, b) a growth engine that allows one to represent growth scenarios without equilibrium, thus offering new insights as compared to conventional general equilibrium models. We analyse three scenarios: the reference no-constrained (Business as usual) scenario; the world 450 ppm scenario applied to Brazil with no ethanol exports;, the same with an ethanol export scheme aiming at the level of 5% of the world demand. The scenarios have been analyzed through our dynamic general equilibrium model Imaclim-R.

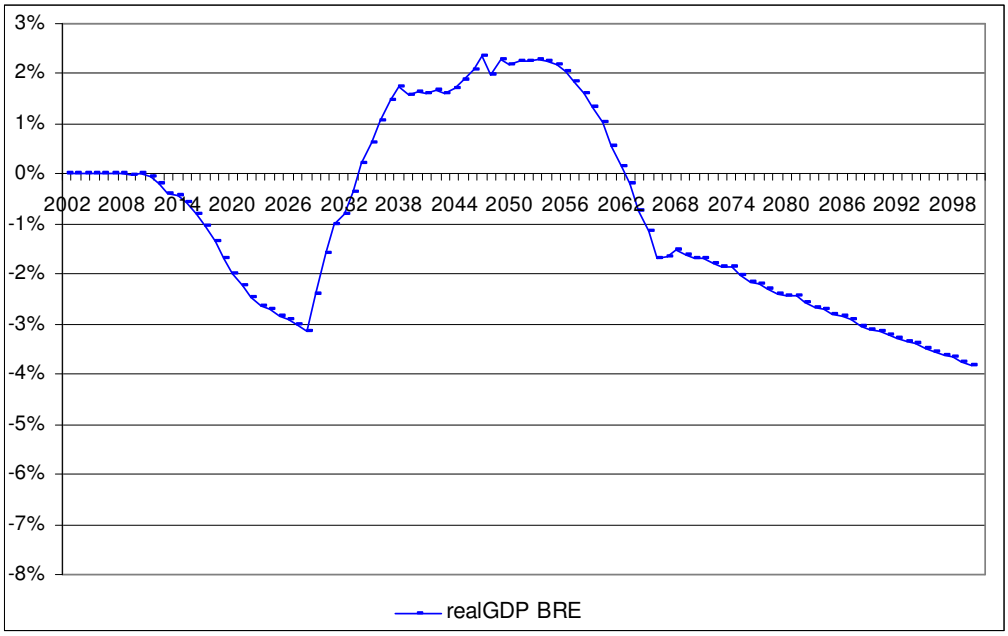
4.1. Brazil and the transition costs of a 450 stabilization scenario

The aim of this paper is to disentangle the numerous dimensions of the climate-development nexus in the Brazilian case, and this effort would be diluted and its main conclusions blurred in an analysis embarking from the multiple variants of post-Kyoto institutional arrangements (type of quota allocations, permit trade patterns). This is why we selected an abstract perspective of a 450 ppm scenario in which all regions face the same carbon price and abate at the same marginal cost. This heuristic stylization holds with the heroic assumption that a benevolent planner knows all data perfectly so as to be able to allocate exactly the quotas in such a way that no trade would take place in a world-wide cap-and-trade system. In other words, if a country would like to import one ton of carbon, for any exogenous reason, this import would occur at this carbon price. For the sake of simplicity, this “modelled” world price follows a linear growth rate.

4.1.1. Phases of losses and gains for Brazil

Comparing the 450 ppm scenario GDP path followed in Brazil to the Brazil GDP path in the reference scenario (i.e. with no-carbon constraint), we find a counter-intuitive pattern. The global 450 ppm constraint created a GDP loss at the beginning and at the end of the 100-year simulation, and a GDP gain for about 30 years from around 2033 to the early 2060s (see Figure 2). Rather than the precise GDP differential values and their turning dates, we are interested here in identifying the parameters and the mechanisms that explain such a surprising result before understanding what a huge ethanol export scheme could do for Brazil in a world 450 ppm climate constraint regime.

Figure. 2. GDP loss or gain for Brazil in a world 450 ppm scenario.



Source: CIRED

These ups and downs of GDP variations compared with the reference scenario can be explained by the interplay between the following factors:

- the role of oil and gas imports expressed in volume and aggregate trade flows;
- the share of energy expenses in the household budget;
- the country terms of trade;
- the share of the energy sector in the total investment of the economy.

4.1.2. An alleviated oil and gas import bill

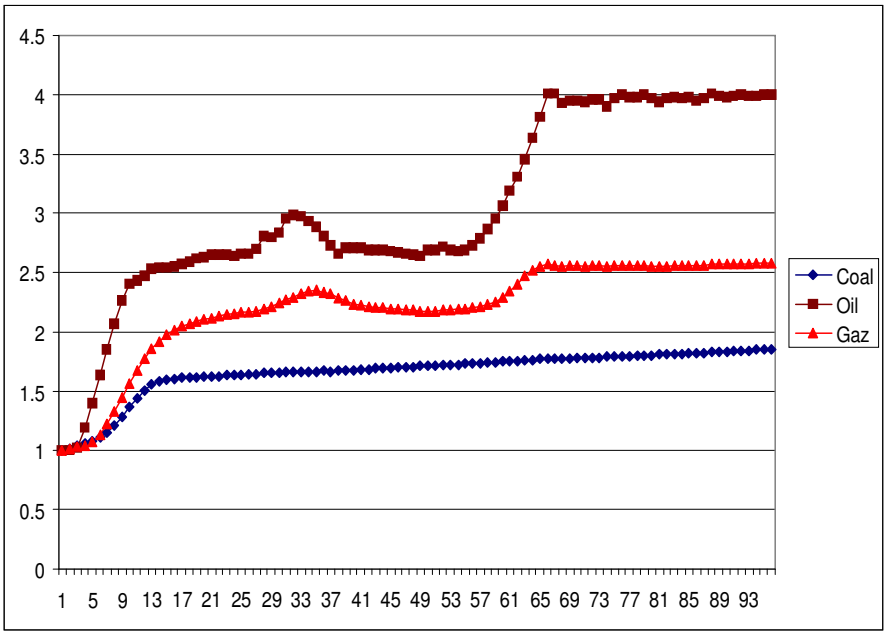
The 450 ppm carbon constraint provokes a lower oil and gas demand on the world market, so that the export income flows to the Mid-East region decrease. The paradox is that this switch from the oil and gas rental income to a 450 ppm based carbon tax, postpones by more than three decades the date when the increasing world price for each fossil fuel reaches its asymptotic value exogenously defined by the cost of the coal to liquid conversion technology.

In both the reference and 450 ppm scenario, the price of oil is multiplied by four compared with the 2004 prices and the price of gas by 2.6; but in the 450 ppm scenario, this plateau is reached late at the end of the sixth decade of the 450 ppm scenario (see Figure 3).

For importing countries including Brazil this price pattern alleviates the oil and gas dependency. In fact, we can see that the 450 ppm world price path for oil and gas is coincidental both in time and intensity with the GDP counter-intuitive path. The links are mainly due to two favorable effects:

- the lower energy bill for both households and industry
- a strong betterment of the terms of trade, and thus a lower import bill for Brazil.

Figure 3. Evolution of the fossil fuel prices in the 450 ppm scenario.



Source: CIRED

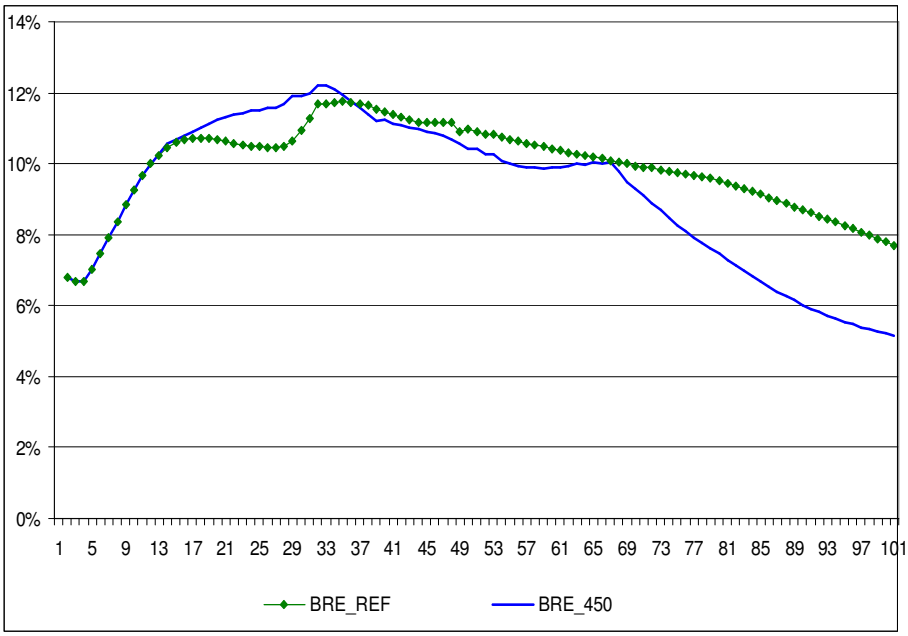
4.1.3. Evolution of the energy share in the household budget.

The energy bill for households is driven by three factors:

- the carbon price;
- the real income, which increases with the development through time;
- induced technical progress.

In the reference scenario (i.e. a no-carbon constraint world), the energy bill in Brazil follows a soaring trend due to the unfavourable terms of trade and to the large sections of the middle classes moving to a more energy-intensive consumption pattern. The 450 ppm scenario creates a carbon price which immediately increases by 0.1% per year the relative share of the household energy budget (see Figure 4). This is due to an inertia factor (the efficiency of existing equipment stock and the technical and social limits to accelerating its obsolescence rate), which lasts about 15 years before the counterbalancing effect of the autonomous energy efficiency progress comes into play combined with a technological and socio-economic response to the increasing energy consumer cost. The final decades accentuate this trend of a decreasing share of energy expenditures for households, despite the counter-effect of a rebound effect on mobility demand.

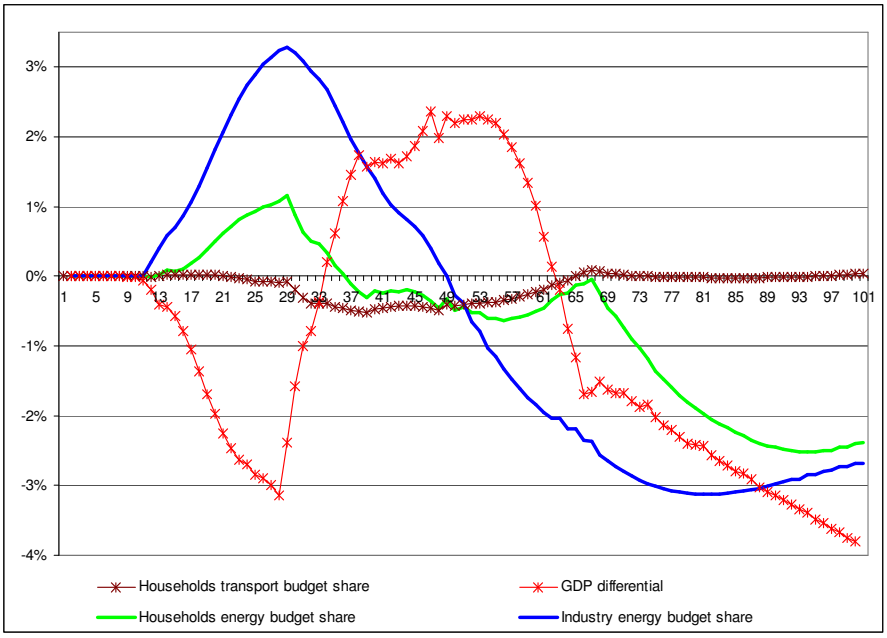
Figure 4. Energy expenses as a household budget share for the two scenarios.



Source: CIRED

It is to be stressed that the date at which the GDP losses start diminishing coincides with the bifurcation date to a decreasing energy share trend. This is due to the fact that the energy demand has a high priority in the household budget; its increase generates an adverse income effect that lowers the purchasing power of non-energy, which in turn impacts heavily on the GDP growth rate. Why then does the same decreasing trend (minus 1.5 % of the energy budget share) continue during the last third of the century but no longer coincide with a positive effect on GDP? The reason is found in Figure 4a., which shows the time profile of variations of GDP, the pathways of the household budget share allocated to transport and to energy expenditure, and, finally, the industry budget share allocated to energy. In short, the increase in the transport budget share in the middle of the period reveals a rebound effect of mobility demand, which cannot be compensated without a proactive set of infrastructural and real estate policies. This requires finding ways of avoiding irreversible mobility needs that are built into urban sprawl. This effect was already identified by Crassous et al.(2006) who suggest that the carbon price cannot by itself provide a way out of such a lock-in.

Figure 4a. Path differences of the 450 ppm scenario as compared to the reference scenario: GDP; household budget share on transport and on energy; industry budget share on energy.

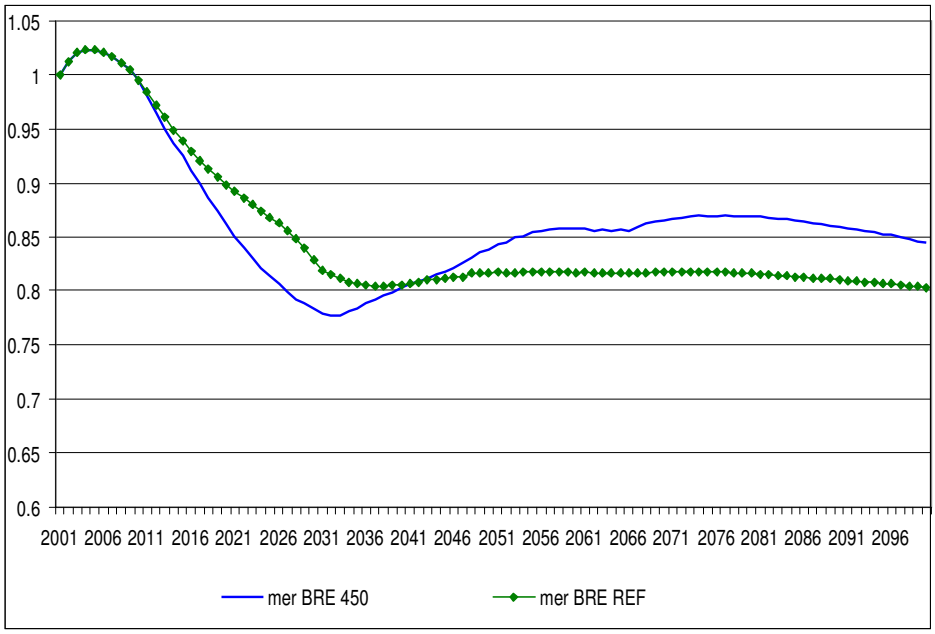


Source: CIRED

4.1.4. Role of balance of trade and of energy cost in production

In the reference scenario, the balance of trade of Brazil follows the same pattern as other emerging countries. During most of the 100 year period, the real wage increases more rapidly than the labour productivity, while the high growth puts the balance of trade under the pressure of higher import of capital and consumption goods and more importantly of energy in the context of rising oil prices. After this long transition period Brazil has made up most of its initial wage and productivity lag and the terms of trade follow a reverse trend (see Figure 5).

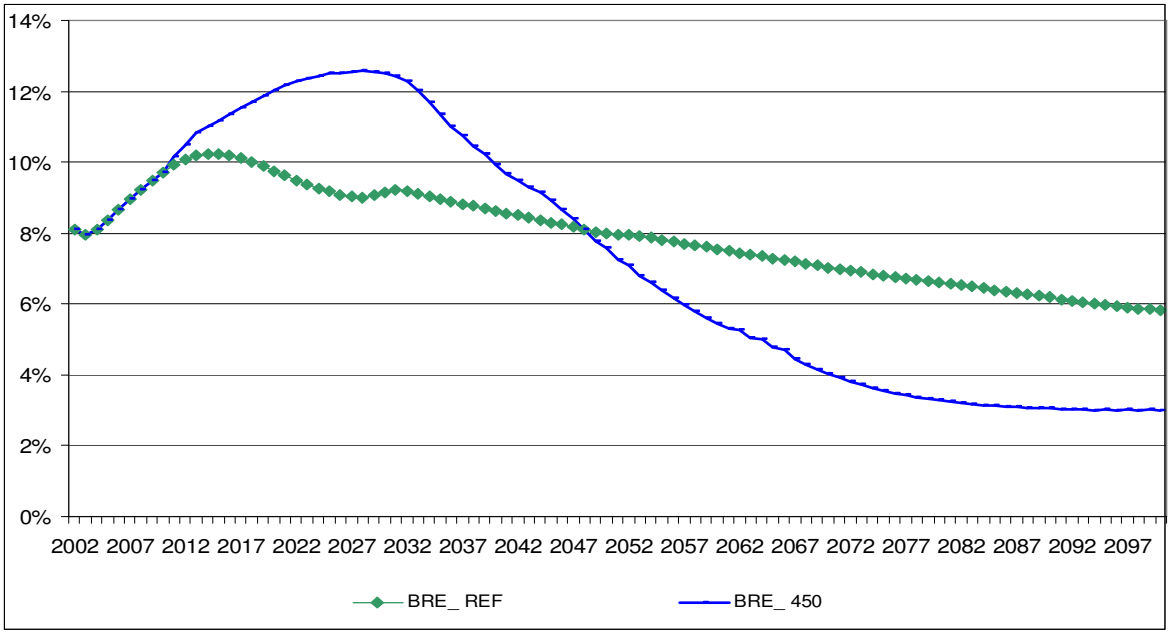
Figure 5. Evolution of Brazil balance of trade in two scenarios.



Source: CIRED

The 450 ppm carbon constraint decreases still more rapidly the terms of trade reaching up to more than 20% below the reference case up to the 2030s due to various mechanisms. The main reason is the increase (especially from 2010 to 2042) of the energy component in the production cost of non-energy goods (see Figure 6).

Figure 6. Energy cost component in the production cost of non-energy goods.



Source: CIRED

Beyond 2050, the trend is reversed. In the long run, the 450 ppm constraint induces energy efficiency gains and lower fossil export prices, which allows Brazil to reduce its energy import bill. Balance of trade can thus improve. In turn the more favourable balance of trade triggers a higher demand due to a lower cost of the imported component of Brazilian consumption. In other words, the purchasing power of Brazil improves in the long run.

In total the carbon price has negative impacts on the Brazilian economy in the first period until an induced technical progress reverses the GDP situation as compared to the reference path. The net cost of the 450 ppm carbon constraint is not at its apex when the carbon tax reaches about 800$/tC in 2050 but in the short and medium run when the country faces the challenges of a more basic development stage. Thus the transition period to 2030 presents a difficult challenge and this may prevent Brazil from adhering to an internationally coordinated regime of climate policies.

4.2. Managing the 450 ppm transition loss for Brazil through large-scale exports of ethanol?

We have seen that Brazil would face its most challenging transition in the period up to 2030 in the case of a 450 ppm scenario, though it is not so vulnerable as some other emerging economies. Beyond 2060, the net cost for Brazil could presumably be more sustainable if a set of low carbon technologies would offer the world a new carbon deal for reconciling climate and growth. From 2030 to 2060 the second generation bio-fuels might come into the picture. But it is difficult to assess this for Brazil because of the diversity of unknown factors such as the type of technology and what would it imply for the distribution of human settlements in Brazil and the valorization of biomass beyond ethanol.

In the absence of a GE model for Brazil capable of integrating such land-use variables, we tested the new modeling structure elaborated during the MATISSE project to capture the impact on land rents

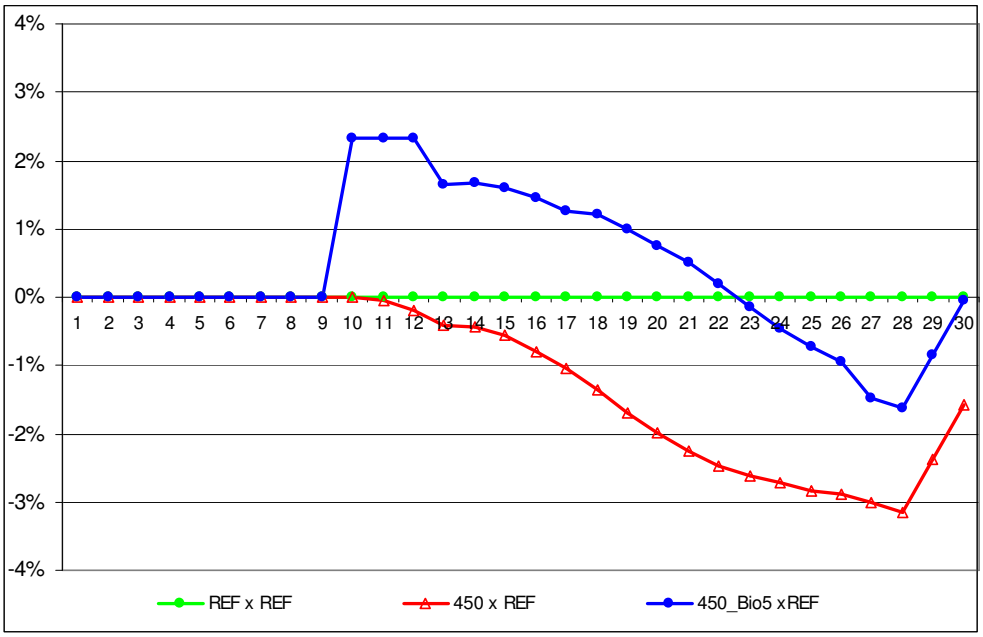
and on food prices But we decided to concentrate on the hypothesis of large exports of ethanol over the period between 2005 and 2030 for two reasons. The first is that this is the sensitive period for Brazil in a decarbonization strategy, the second is the availability of a reasonable set of expertise on data such as land and industrial productivity. Such a set of data was published just at the start of our MATISSE effort by a Unicamp study (see Annex), which assessed a possible program in Brazil for exporting ethanol by up to 5% of the world gasoline demand in 2030. We thus decided to embark on feeding those Unicamp expert data into our Imaclim-R land-use compact model.

We test two variants with two contrasting land use hypotheses. With unconstrained land allocation, the biofuel expansion displaces other crops and by a domino effect it encroaches on the forest. At the other extreme is the ethanol expansion variant with no new land converted to crops. The environmental cost is assessed as the loss of natural environment. The social cost is assessed as the impact on the price of food and the income for the poor population.

Figure 7 represents the impact on GDP of the Brazilian ethanol export program at 5% of the global market, as compared to the 450 ppm scenario in Brazil, and to the reference path in Brazil. The huge ethanol export program has a strong positive impact on the GDP path, which is above the reference path with the exception of the 23 to 30 year period. The GDP differential to the 450 ppm path is above 2 percentage points on the 9 to 26 year period. This is explained by the impact of the biofuel export on the balance of trade and on the energy bill for industry and households, in turn explained by the lower oil and gas prices.

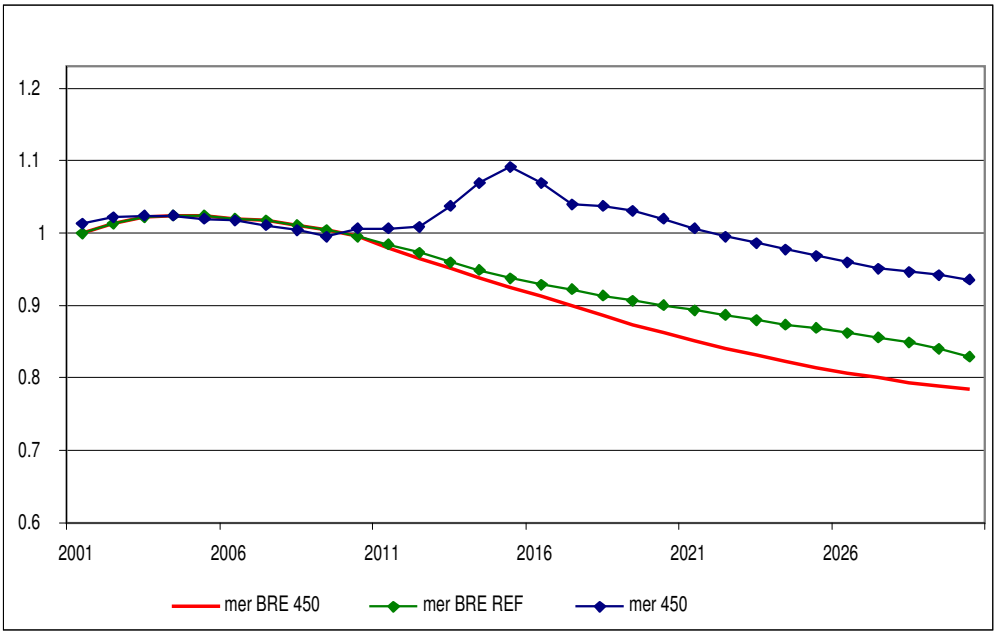
Figure 8 shows that the biofuel export at a level of 25 billion US $ in 2030 has a strong trade balance impact of about 12 percentage point above the 450 ppm path. The stronger real purchasing power on foreign markets has a positive impact on the local activity measured by the GDP.

Figure 7. GDP differences in Brazil between the reference case, the 450 ppm and the 450 + biofuels 5% Exports



Source: CIRED

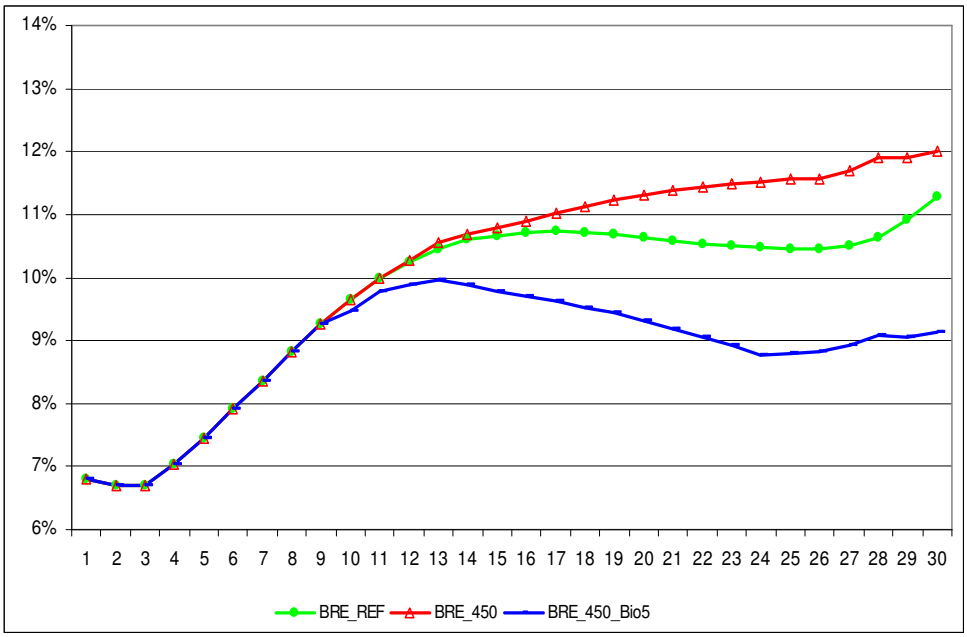
Figure 8. Balance of trade path for 3 scenarios for Brazil



Source: CIRED

Figure 9 shows that the household energy budget share is lower in the ethanol export program than in the 450 ppm and even as compared to the reference scenario. This path is strongly correlated to the market exchange rate path. The link is indirect. The better exchange rate combined with the lower prices of oil and gas (see Figure 9) result in an increased household purchasing power, and thus a higher domestic demand.

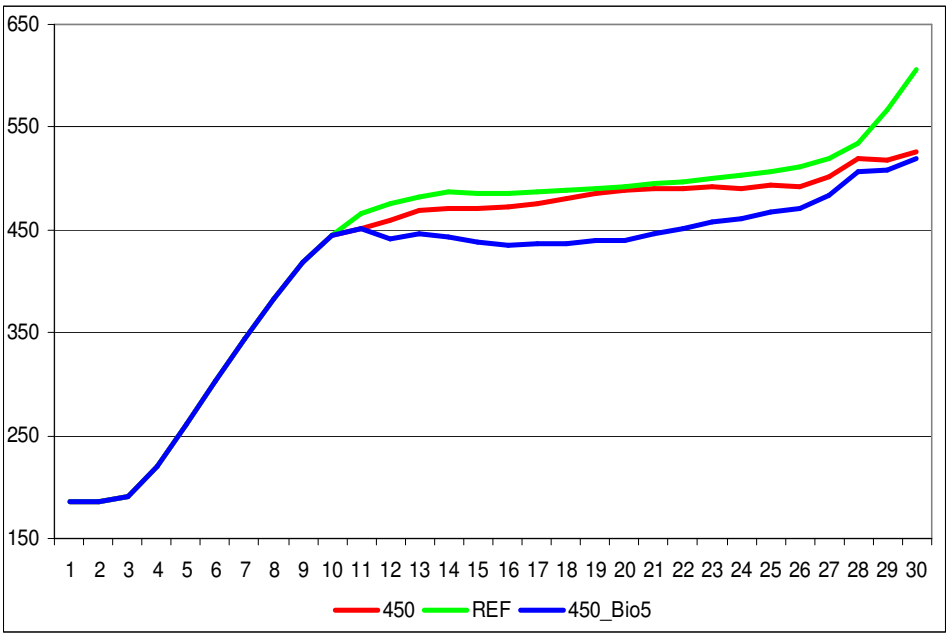
Figure 9. Brazilian household energy bill path in three scenarios



Source: CIRED

The world oil price is at its lowest in the 450 ppm with biofuel export program. An oil price reaching about 10% below the reference scenario affects the gas price and the price of the competing energies and this explains most of the lowering of the household energy budget share.

Figure 10. World oil price path for three scenarios



Source: CIRED

Lastly, the 5% biofuel component alleviates the oil refinery sector capacity constraint, a secondary factor contributing to lowering of the energy bill. In the reference scenario, pressures on the oil refining sector continue due to the difficulty in mobilizing investments quickly enough to meet an exploding demand. Refineries thus never operate at their optimal capacity. This is no longer the case with the slowdown of refining needs in the oil industry due to a higher penetration of biofuels.

Thus in the scenario of a world 450 ppm stabilization scenario with a market represented through a unique carbon price, Brazilian cane-derived ethanol has a multifaceted comparative advantage in terms of yield, environment and production cost, which led us to simulate the impact of an export program amouting to 5% of the projected world gasoline demand in 2050[5]. The strict 450 ppm stabilization constraint depresses the oil and gas world price allowing a decrease of the energy budget share both for household and industry.[2] The remaining issue is the overall impact of such a strategy on development, the major concern being about its impact on food prices and the income level of fragile populations.

4.3. Impact of a large scale exports of ethanol on land use and food prices

To understand the specific development implications of large scale exports of biofuels, we first analyze a hypothetical policy scenario in which Brazil adheres to a 450 ppm agreement but uses only a domestic carbon tax to achieve it and does not export biofuels beyond the baseline (for example, due to disputes in Annex 1 countries about the ultimate impact of this technology). In such a scenario (denoted TAX), the ethanol area reaches 21 M ha in 2025, all for the domestic market (see Table 2). This amount has to be compared with 4 M ha today and 18.6 in the reference scenario in 2035,

[5] According to the *International Energy Agency World Energy Outlook*

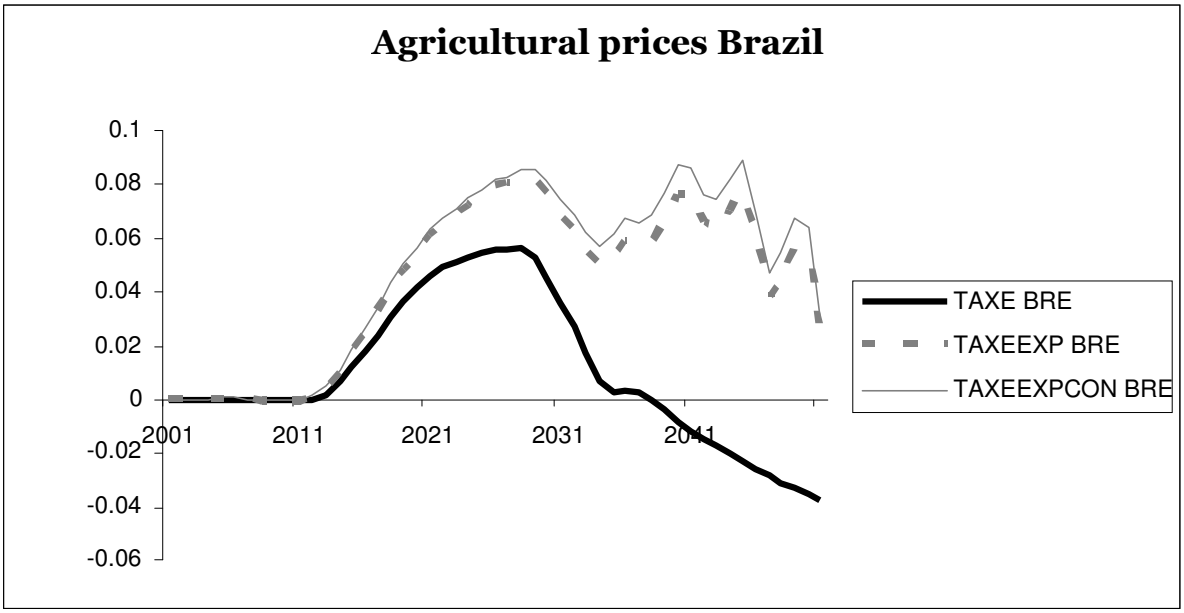
including 5 M ha for exports. Around 2025 the food prices are 6 % above what they are in the Reference scenario (see Figure 11). This food price pressure results from the carbon constraint (2011) and it comes back to nil slightly before 2040.

SCENARIO	Ethanol production (M tep)	Ethanol Area Mha (including exports	Scenario details
	9	4	Starting in 2010
	2025	2025	Scenario (2011-2050)
REF	70	18.6	Reference (**) case (no carbon constraint)
TAX	79	21	Tax (quotas for a 450 ppm stabilization) no export
TAX EXP	79	21	Tax+Exp (same 450 ppm + Bio5% export)
TAX EXP CON (*)	70	18.6	Tax+Exp+Con (*) (with a ceiling of 20 M ha on the total additional cropped land)

Table 2. Bio-Ethanol data in various scenarios for Brazil (2010-2035)

(*)TAX EXP CON: In this variant CON stands for land constraint. We assume that the total cropped area is limited to 80 M ha in 2025 (including the ethanol-derived sugar cane), whereas the 2006 cropped area is 60 M ha, including 6 M ha in cane in 2006.

Figure 11. Impact of three scenarios on agricultural prices comparing to the reference scenario



Source: CIRED

Through time, the pressure decreases after a peak of the additional land allocated to ethanol around 2021. The major information from this simulation is the existence of a peak in the increase of food prices compared with the baseline. This is obviously due to the fact that the control on mobility in Brazil and in the world lowers the demand for fuel. The food price differential disappears around 2021 and this results from the control of mobility needs in a 450 ppm scenario.

This good news no longer holds in the Tax-Exp scenario. In this scenario, we combine the 450 ppm constraint with an ethanol export program, reaching 5% of the world biofuel demand in 2025. It results in the following:

the food price increases up to nearly 8% compared with baseline instead of 5% in the tax only scenario;

the total of the additional land allocated to ethanol remains at 21 M ha in 2025 ;

the gap between this TAX-EXP scenario and the TAXE (only) widens beyond 2028 and peaks around 2041;

Let us try first to explain the most intriguing results before commenting upon the increase in food prices. In the TAX + EXP + CON, the previous scenario is submitted to a land constraint of 80 M ha for the total cropped land (20 Mh above the 2006-10 level). This land ceiling constraint leads to the total ethanol land allocation set at a ceiling of 18.6 M Ha ; the food prices are pushed slightly upwards by about 0.5% (starting from almost 7% up to 8.3%).

The easiest to explain is that the increase in food prices starts diminishing before 2045 instead of 2028 in the tax only scenario. This results simply from the fact that ethanol production is driven by world demand. This world demand for ethanol results from the higher competitiveness of this energy in a 450 ppm world and from the aggregate evolution of world demand for fuels. This latter effect, driven by a lower increase in mobility needs, starts compensating for the former only beyond 2045 at the world scale whereas, the share of ethanol in Brazil is almost 100% as early as 2025. Therefore it is not long before the reduction of mobility drives a reduction in ethanol demand.

More intriguing is the unchanged amount of land dedicated to the production of ethanol in the export scenario. This is totally due to the technical inertia incorporated in the Nexus-Imaclim structure. As for the oil refineries, this is due to the inertia in deploying the infrastructure for converting sugar cane into ethanol. Secondly there is limit on the rate of displacement of the geographical frontier of sugar cane production, including the deployment of transportation infrastructures. These two constraints have been placed in accordance with local expertise and it happens that they met in any 450 ppm scenario (which was not expected ex-ante). Perhaps both inertia assumptions are too pessimistic but the simulation modeling underlines again the role of technical and institutional inertia, which are neglected in many analyses.

The existence of these deployment constraints explains why the main difference between the export and tax only scenario lies in the allocation of land between domestic and export markets. In the tax only scenario, 21 M ha are devoted to domestic consumption, whereas one third if this area is devoted to foreign markets in the export scenario with Brazil covering the rest of its fuel demand by domestic and imported oil.

This result may seem surprising in the sense that a lot of attention is currently devoted to the impact of biofuel production on food prices. However it can be easily explained by the fact that the decrease in available land between the two scenarios is only 11%, which is consistent with a maximum additional increase of 18% in food prices. But this increase quickly diminishes thanks to the intensification of agriculture as a response to limits on land availability and to the decreasing trend of ethanol export demand. But in total, this result simply confirms that the US situation (which triggered tensions regarding the price of basic food in Mexico) is by no way comparable with the Brazilian one. In Brazil indeed, the amount of land is not constrained; the main issues are the protection of natural lands and the domino effect from higher production of ethanol to the conversion of new pasture land and forest into agricultural lands.

5. Conclusion

The main conclusion of this paper is not substantive in nature, although we venture to think that some useful policy insights can be derived from it: a) the contribution of biofuels to lower the transition costs imposed on Brazil by tight carbon constraints, b) the impact of large exports of ethanol on oil prices, c) the fact that the increase in ethanol production leads to significant increase in food prices in Brazil (from 5.5% to 8.3% depending on the limits on land) which may offset the overall economic benefits of this strategy for the low income population.

The main conclusion is methodological in nature since the above insights, although preliminary, could not have been delivered without a modeling tool allowing first the representation of disequilibrium pathways and endogenous technical change. The importance of that can be seen in the unevenness of GDP variations between our reference and policy scenarios, whereas the conventional models tend to represent cost curves smoothly increasing over time. The second lesson is about the importance of a transparent tool to convey engineering and geographical information, based on physical indicators into the value flows of any economic model. This transparency helps in particular in better understanding the ultimate importance of controversial views about technology.

The last conclusion is that this new generation of models, with these three characteristics of a dual description of the economy in physical and value flow, of an endogenous description of technical change and of a growth engine allowing for transitory disequilibrium, will not provide credible policy insights until they are elaborated in a collaborative way with scientists and actors that can control the quality and relevance of information on local mechanisms and specific contexts (in this paper through CIRED a long standing collaboration with Brazilian experts). In addition to serving as a communication language between disciplines they should aim at bridging the aggregation gap between local and global analysis of sustainability issues.

Annex: Ethanol expansion program for Brazil

The aim of the project is to simulate the economic impacts in the Brazilian economy of an increase in the domestic sugar-cane ethanol production. Some scenarios will be built in order to assess the opportunity costs for land use and energy use from biomass and its impact on GDP, due to distinct increases in the amount of ethanol production under the most likely technological options for the near future. Some studies have already tried to simulate the impacts on GDP due to an increase in ethanol production. However they have not addressed the question of what would be the optimal export level for Brazilian ethanol or even the equilibrium price for ethanol under distinct levels of world ethanol demand.

This is the case of the most recent study ordered by the Brazilian government to Unicamp (Universidade Estadual de Campinas). It simulated the impacts on the domestic economy if the ethanol production increased in order to meet the domestic demand and also to replace 5 or 10 percent of the international demand for gasoline up to 2025. In this case, the demand and the price are exogenous factors, not a result of the analysis. It is worth mentioning that ethanol can be added to pure gasoline up to 25% in volume without special technology adjustments on the fleet or can be used as an input to produce ETBE (a gasoline additive). This makes ethanol a perfect substitute for gasoline in the international market as required by the simulations to be done by Imaclim.

The simulations also rest on the fact that the Brazilian ethanol has highly competitive prices and therefore the international commercial barriers (or local subsidies and other political measures that support local deficient production) from potential buyers could fall at anytime.A comparison among the production costs worldwide is given in Table A.1.

Country	**Anhydrous ethanol cost production**		**Raw material**
	US$/liter[(1)]	**US$/liter**[(2)]	
Brazil		0.20	sugar-cane
Center-South	0.15		sugar-cane
North-Northeast	0.18		sugar-cane
USA	0.33	0.47	corn
Europe	0.55	0.97	beet, wheat
Thailand		0.29	sugar-cane
Australia		0.32	sugar-cane

Table A.1. Ethanol production cost: an international comparison

Source: [(1)] Governor`s Ethanol Coalition/UNICAMP; [(2)] Datagro. Note: US$ 1 = R$ 2.5 (average currency exchange rate of 2005). Source: UNICAMP (2005)

The study conducted by Unicamp (University of Campinas, 2005) has tested the hypothesis, where the ethanol would substitute 5% of the world demand for gasoline. The main assumptions of this study are as follows.

Synthesis of the Main Assumptions and Results of the Unicamp Simulation with Exogenous Demand and Price for the Brazilian Ethanol

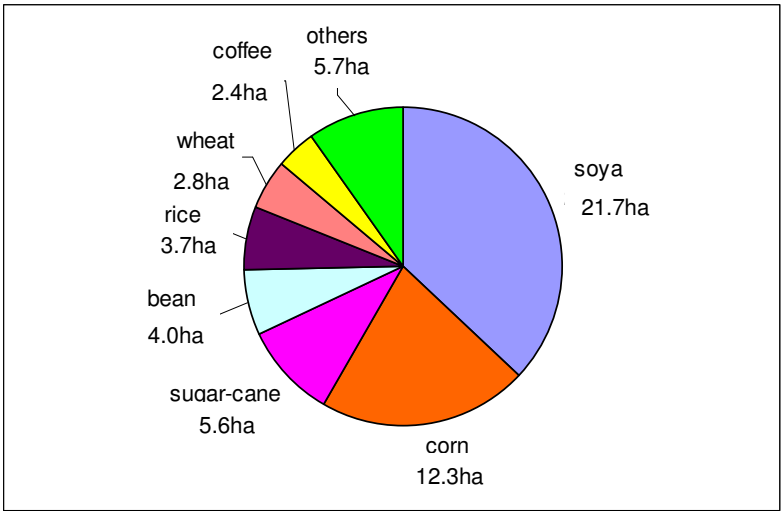
1 Potential Market

Gasoline is mainly used in the light duty fleet that nowadays consumes more than 1.15 trillion liters of gasoline per year. It is foreseen that in 2025 this fuel consumption would be 48% higher, demanding approximately 1.7 trillion liters (EIA, 2004). To supply 5% of such demand, Brazil would need to produce an extra amount of 102.5 billion liters of ethanol per year,[6] which would require 17.5 million hectares of land, less than 20% of the available area that does not require irrigation.

2 Current domestic sugar-cane and ethanol production profile

Brazilian ethanol is made from sugar cane with crops producing 31% of the world sugar-cane production. They occupy 5.6 x 10^6 hectares of land, which ranks third in extension in the country, just after soya and corn, as presented in the following figure.

Figure A.1. Area allocation in Brazil (million hectares)



Source: IBGE 2004

The country production of sugar-cane and ethanol is divided between two main areas: the Center-South Region and the North-Northeast Region, as plotted in the following figure.

[6] In general, a liter of anhydrous ethanol can substitute 0.8 liters of gasoline. When mixed with gasoline in a small proportion, we can assume that one liter of ethanol substitutes one liter of gasoline.

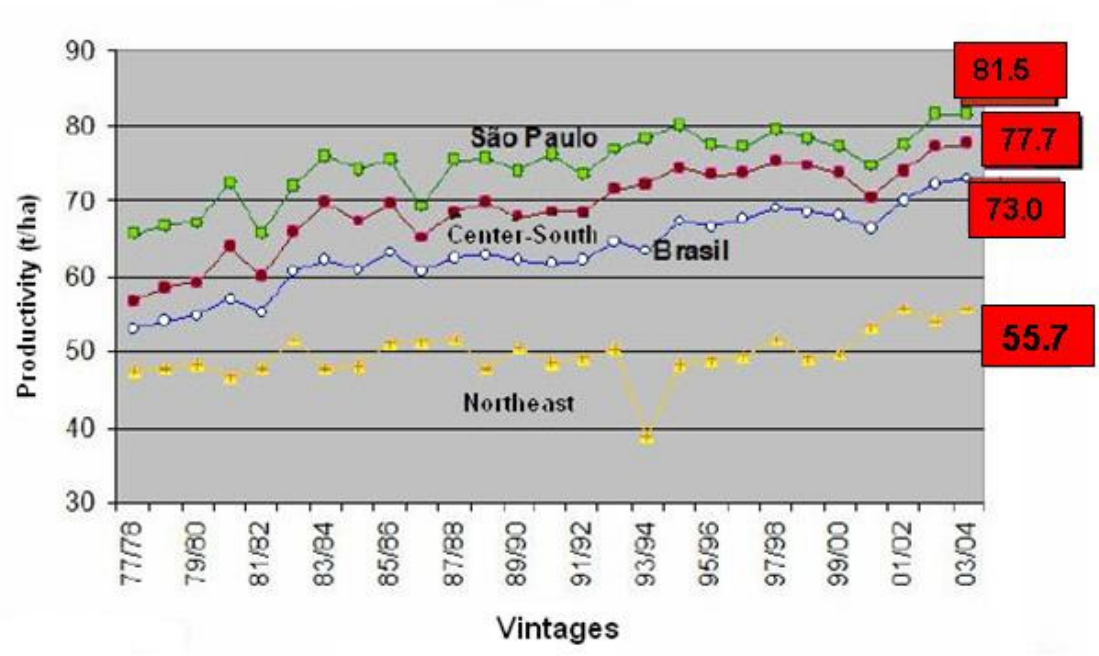
Figure A.2. Distribution of the sugar-cane plants in Brazil

Source: UNICAMP

The sugar-cane from the Center-South Region is responsible for 85% of the total Brazilian production and it goes from April to November. In the North-Northeast Region, the remaining 15% is produced from September to March. Gains of productivity in the sugar-cane crops have been increasing since the seventies and are mainly due to genetic improvement of seeds, harvesting mechanization (that reached 34% of the whole harvested area in the Center-South Region in 2005 but is still not in practice in the North-Northeast Region), biological control of pests, effluent recycle and agricultural best management practices[7] . No genetically modified sugar-cane seeds are being used in the country.

[7] Planting mechanization is not taking place in the whole country

Figure A.3. Agricultural cane yield per region in Brazil



Source: IBGE, 2003

There are two kinds of sugar-cane mills: those that produce only sugar and those that produce both sugar and ethanol. Distilleries produce just ethanol. In 2002, there were 318 production units as below:

Sugar-cane mills: 15

Mills with distilleries (flexible mills): 199

Autonomous distilleries: 104

The efficiency of the mills varies according to the share of ethanol and sugar production in each one. Distilleries are able to produce up to 85 liters of ethanol per ton of sugar-cane (maximum value obtained in an efficient plant). The environmental consequences of the sugar-cane and of the ethanol production are relevant aspects to be considered when expansion of the production is under assessment. According to Unicamp (2005), it is important to compare the ethanol production to the alternative uses of land and water and to other industrial processes that would take place if no increase in the production of ethanol were observed. Impacts like erosion, biodiversity damage, use of chemicals, emissions, etc., must be assessed considering the cane replacing extensive grazing or orange crops, as it has been happening, or natural biomes like Cerrado and forests in other cases.

The production of sugar cane and ethanol in Brazil today has interesting environmental features: low use of agricultural pesticides; efficient and comprehensive biological control of pests; lowest level of soil depletion in the agricultural sector; efficient recycling of all waste produced; and no threats to the quality of water resources. However, it is worth mentioning that although there is no need for crop irrigation, the ethanol production requires huge amounts of water and a better knowledge about the water availability is still required.

To simulate the outcomes of an expansion in the ethanol production to meet 5% of the world gasoline demand in 2025 (102.5 billion liters of ethanol), it is assumed that the best practice management

would be adopted by farmers and ethanol producers and that the best available land would be converted into sugar-cane crops. It is very important to stress that the projections were made based solely on the first generation technology for ethanol production. Moreover, Brazil has a big diversity in types of soil and climate conditions because of its continental dimensions, resulting in a wide range of potential for agricultural use of land. This diversity, together with the limitations imposed by slopes[8] and by environmentally sensitive regions like the Amazon, the Pantanal, the Atlantic forest, the ecological reserves, etc., demanded an integrated assessment in order to identify those areas suited to the expansion of the sugar-cane crops.

Considering that on part of this land there are already other crops and that therefore it would be excluded from the total area to be converted in cane crops, 28.4 M ha is left to be dedicated to the expansion of ethanol production in Brazil as compared to the current 200 M ha allocated to cattle raising and the 60 M ha of cropped area including 6 M ha for sugar cane. The Center-South Region would convert 60% of the total demanded area while the North-Northeast would convert 40%. Taking into consideration that one agro business unit takes four years to be operational from its conception, the following schedule for ethanol availability would be possible.

Vintage	00/01	05/06	09/10	14/15	19/20	24/25
Anhydrous ethanol	(mil m3)					
- N-NE	818.6	911.0	2,353.6	4,701.5	13,713.8	44,306.5
(%)	14.6	11.1	20.8	26.8	34.8	39.3
- C-S	4,802.4	7,331.4	8,982.5	12,835.0	25,683.0	68,513.2
(%)	85.4	89.9	79.2	73.2	65.2	60.7
Total	5,621.0	8,242.4	11,336.1	17,537.5	39,396.8	112,819.7

Table A.2. Increase in the Ethanol Production for Export Purposes

Unicamp (2005) assumes that: the new areas dedicated to the extension of ethanol production would be based on the following principles aimed at capturing scale economies.

The distilleries would be set in clusters of 15 plants in order to facilitate the transport of the ethanol to ports by pipelines (considered the best cost-effective transport option).

They would total 615 new plants.

Land productivity would have an average efficiency of 71.5 tonnes of sugar-cane per hectare.

A standard distillery in the cluster would process 2 million tons of sugar-cane per year.

Each distillery would require an area of 35,000 hectares of sugar-cane (with 20% of them being used as environmental reserves as determined by law).

Distillery productivity would have an average efficiency of 85 liters of anhydrous ethanol per ton of sugar-cane.

The average production of one distillery would be 170 m3 of ethanol per year.

All harvesting would be mechanical[9].

[8] Areas with 12% slope or more are not suited to sugar-cane crops.

[9] In São Paulo, the state which produces most ethanol in Brazil, the law 10.547 from 2000, due to environment concerns, established a schedule to banish the use of fire in harvesting in 20 years. Other states may follow this path.

With respect to the costs, the projections rely on the following data:

	Real $ per ton	%
Sugar-cane cost	390.12	68.5%
Industrial costs	132.7	23.3%
Management costs	46.87	8.2%
	569.69	100.0%

Table A.3. Production Costs in a Standard Distillery

Note: US$ 1 = R$ 2.5 (average currency exchange rate of 2005)

Source: Unicamp

The costs above can be broken down into the following:

	R$/ton	%
Crop formation	5.56	16.8%
Handling of the plant	1.07	3.2%
Handling of the roots	879	26.5%
Harvest and transport	11.1	33.5%
Agricultural management	1.33	4.0%
Land remuneration	5.31	16.0%
total	33.16	100.0%

Table A.4. Sugar-cane Average Production Costs

Note: US$ 1 = R$ 2.5 (average currency exchange rate of 2005)

Source: Unicamp

	R$/ton	%
Wages and social security costs	28.86	21.7%
Depreciation	26.5	20.0%
Chemical products	21.63	16.3%
Lubricant oils	3.43	2.6%
Material for maintenance	20.97	15.8%
Third part services	8.74	6.6%
Others	22.58	17.0%
total	132.71	100.00%

Table A.5. Standard Distillery Average Operational Costs

Source: Unicamp

	R$/ton	%
Wages and social security costs	15.66	33.4%
Third part services	6.41	13.7%
Social assistance	8.96	33.8%
Others	15.84	19.1%
Total	46.87	100.0%

Table A.6. Standard Distillery Average Management Costs

Note: US$ 1 = R$ 2.5 (average currency exchange rate of 2005)

Source: Unicamp

3 Investments

To reach the export target, 615 new distilleries with 2 million tons of cane-processing capacity will be needed. The whole investment in the agro-business is estimated to be R$ 172.2 billion (of 2005) plus R$ 21.3 billion in pipelines and port infrastructure, adding up to R$ 193.5 billion. This amount represents an average investment of R$ 9.676 billion annually, around 0.51% of the GDP in 2004.

The economic assessment uses 2002 values and they are summarized below:

	usine	culture	Pipeline & ports	total
Machines	78.06	3.49	10.72	122.27
Camions		2.20		2.20
Ouvrage civil	9.76	1.78	4.12	15.66
subcontracted services	9.76	0.00	1.65	1.41
total	97.57	37.48	16.48	15.54

Table A.7. Investments (R$ billion – 2002)

Source: Unicamp

4 Income

Considering the costs presented above and the returns that the investments require, the ethanol FOB price should be at least US$ 0.30 per liter approximately, equivalent to US$ 48.0 for an oil barrel. This would total US$ 31.4 billion in 2025. Brazilian total exports reached US$ 117.0 billion in 2005. The foreseen ethanol exports would then represent 27% of the current total exports in 2025, a huge impact on the balance of payments.

5 Other Relevant Aspects

Electricity generation in Brazil is mainly based on hydropower plants (80% approximately). However, the system is being expanded and the opportunities for hydro generation occur in the Amazon Region that is very distant from the consumer centers and there are great environmental concerns due to the threats to the rainforest. Recent bids for electricity supply show that coal plants are very likely to become an important source, which raises environmental concerns because of the global warming implications.

In this sense, the expansion of the ethanol production could provide the national grid with an extra amount of energy of 4 kWh per ton of sugar beyond the electricity needs of the ethanol production itself. This amounts to an annual supply of 4920 GWh.

6 Economic Assessment

An economic analysis of the impacts on the Brazilian economy due to an increase in the ethanol production was performed using a 1996 input-output matrix updated to 2002. This matrix was also expanded to incorporate distinct production processes (with and without mechanical harvesting and its impacts on labor). The above UNICAMP data have been adapted to our Imaclim-R and Imaclim Land use modeling tool.

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