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Climate Change and Energy Use in Long-Run Growth in Brazil

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Summary

The objective of this paper is to analyze the expected changes in the energy use composition in Brazil in a context of global climate changes. A trend scenario for the period 2008-2035 is presented, in which a global economic scenario drives the Brazilian economic scenario which, by its turn, drives the 27 states' economic scenarios. A multiregional CGE model is computed, leading to the analysis of sectoral and regional changes. Some adaptation is simulated which led to a change in the energy use composition. The most competitive sectors and regions are pointed out.

1. Introduction

This paper is part of a larger study on the socioeconomic impacts of climate change in Brazil in this Century[1]. The study involves a multidisciplinary team of researchers, including experts in meteorology, water, energy, agriculture, demographics, health, etc. Given global climate change scenarios, the effects of climate change forecasts for the period 2008-2100 on water supply (availability, regularity, river flows, etc.) were estimated. From these estimates, the expected effects on hydro energy production and on agriculture were pointed out. The combined effects of all those impacts were then included in a multiregional Computable General Equilibrium model, which allowed for the calculation of their impacts on GDP growth and employment creation across 55 sectors and 558 regions. In this paper we focus only on the analysis of energy use in the period 2008-2035.

We deal with two global climate change scenarios, taken from the IPCC Report. Scenario A2 "is characterized by lower trade flows, relatively slow capital stock turnover, and slower technological change. … Economic growth is uneven and the income gap between now-industrialized and developing parts of the world does not narrow … People, ideas, and capital are less mobile so that technology diffuses more slowly than in the other scenario families. International disparities in productivity, and hence income per capita, are largely maintained or increased in absolute terms. … Global average per capita income in A2 is low … reaching about US$7200 per capita by 2050 and US$16,000 in 2100. By 2100 the global GDP reaches about US$250 trillion. … Global environmental concerns are relatively weak, although attempts are made to bring regional and local pollution under control and to maintain environmental amenities." The B2 scenario introduces concern for environmental and social sustainability: "Increasingly, government policies and business strategies at the national and local levels are influenced by environmentally aware citizens, with a trend toward local self-reliance and stronger communities. … The population reaches about 10 billion people by 2100 … Income per capita grows at an intermediate rate to reach about US$12,000 by 2050. By 2100 the global economy might expand to reach

[1] www.economiadoclima.org.br

some US$250 trillion. International income differences decrease, although not as rapidly as in storylines of higher global convergence. … Energy systems differ from region to region, depending on the availability of natural resources. … Although globally the energy system remains predominantly hydrocarbon-based to 2100, a gradual transition occurs away from the current share of fossil resources in world energy supply, with a corresponding reduction in carbon intensity." [2]

We produce macroeconomic scenarios compatible with these two global climate scenarios and with some hypotheses about productivity growth in Brazil. These macroeconomic scenarios feed a multiregional Computable General Equilibrium model, allowing for the calculation of impacts of different phenomena on those scenarios at the sectoral level. From the sectoral composition of growth different scenarios for energy use are simulated, leading to the analysis of the composition of energy use in the future. The paper is organized in five sections, including this introduction. In section 2 we present the macroeconomic model that is the benchmark for the sectoral calculations, which are presented in section 3. Some aspects related to energy use are presented in section 4. The conclusions are presented in section 5.

2. Macroeconomic scenarios for the Brazilian economy

The macroeconomic scenarios used in the study establish probable limits for the trajectory of the Brazilian economy under some hypotheses compatible with the A2 and B2 global scenarios. A Dynamic General Equilibrium model is used, considering interactions among five different economic agents: households, firms, the financial sector, government, and the rest of the world (Kanczuk, 2001 and 2003). These agents interact in an economic environment subject to monetary, risk and productivity shocks. The critical element in the construction of such models is the definition of hypotheses relating to these three types of shocks. Given the long-term concern of this study, the first two are not as important, since they are usually short-lived. Therefore they are derived from a sole supposition of global inflation and nominal interest rate trajectories, taken from a world scenario[3].

Trends in productivity, on the other hand, are essential for the determination of economic growth and investment rates. Therefore, they are considered more carefully, involving scenarios for the world economy, as well as scenarios for the internal fiscal policy and institutional framework. A production function is estimated involving capital stock and number of hours worked; the part of production not explained by those two primary factors is considered as the effect of productivity. In what follows the trends in this residual effect is considered. Figure 1 shows its evolution for Brazil and for the US, which is considered the benchmark for any international comparison. It is clear that they evolve in parallel only up to the 1970s; from 1980 on the gap between the two economies has widened. This could be caused by differences in human capital, but Figure 2 shows that this is hardly the case, for the two curves move in parallel.

[2] IPCC Special Report on Emissions Scenarios, Chapter 4 – An Overview of Scenarios
http://www.grida.no/publications/other/ipcc_sr/?src=/climate/ipcc/emission/094.htm
[3] Taken from The Economist Intelligence Unit

Figure 1 – Evolution of Pure Productivity

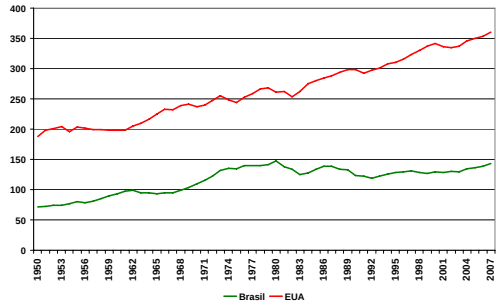
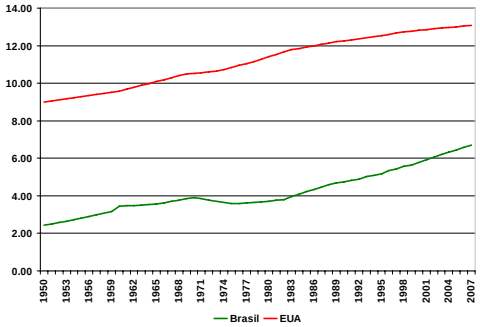


Figure 2 – Evolution of Schooling



The second possible source is distortions to capital accumulation, measured by the relative price of investment goods - price of investment goods in relation to the price of consumption goods (Jones, 1994). These distortions could be associated to bad economic policies and institutions. The most notorious examples are related to fiscal policy, tax policy, and commercial restrictions. Figure 3 presents information on a comparison between Brazil and US in terms of both the relative price of investment goods and the amount the government extracts from the economy and does not give back in terms of investment in capital formation. It is clear that the correlation between both variables is quite high, suggesting that government distortions could be behind the increasing relative price of investment goods.

An interesting exercise is made estimating the comparative trajectories of productivity in both countries excluding these two sources of distortions. The results presented in Figure 4 indicate a clear converge pattern, meaning that the distortions to capital accumulation, mainly caused by government policy, are hurting Brazilian economic growth. In terms of the model used in this study, a convergence coefficient based on these factors is calculated, which is then used as an input for projecting future economic growth in Brazil. Therefore, the scenarios used in the study consider a net productivity convergence of Brazil towards the benchmark economy, the US.

Figure 3 – The relative price of investment goods and government current expenses in Brazil in relation to the US (US = 1)

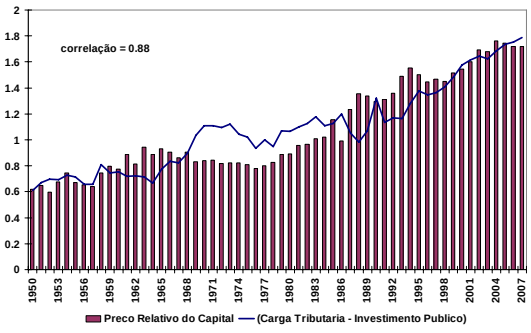
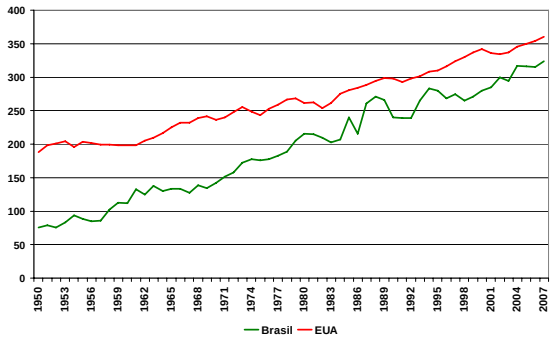


Figure 4 – Evolution of productivity net of schooling and distortions



The international scenarios used in the estimations are related to the IPCC study; the expected rates of growth of GDP employed in this study are displayed in Table 1. It is assumed that the evolution of education in Brazil is faster in B2, but government will have

to increase its size to take care of the increasing expenditure in education. Therefore, the tax burden will be larger in B2, thus compromising faster growth.

Table 1 – Expected GDP growth rates, 2008-2035

GDP annual growth rates	A2	B2
US	2.6	2.4
World	2.8	3.0

The evolution of inflation and nominal and real interest rates is displayed in Table 2. These implicitly determine the trajectories of monetary expansion (monetary shock) and risk, which are key to the estimation of the macroeconomic model

Table 2 – Monetary and risk shocks

	2008-2035
Nominal interest rate (SELIC, %)	10.5
Inflation (IPCA, %)	4.5
Real interest rate (%)	6.0

Figure 5 displays the supposed evolution of education. The numbers reflect an extrapolation of trends presented in Figure 2, and in scenario B2 there is more approximation to US levels. Figure 6 presents the allocation of government expenditures in recent years, showing that the share of investment is small and even declining. The expected distortions to capital accumulation will depend on the evolution of the tax burden and public investments. The first reduces the return of productive projects and capital accumulation; the later have the opposite effect, for investments in infra-structure help economic activity and create incentives for the accumulation of productive capital.

Figure 5 – Supposed evolution of education (years of schooling)

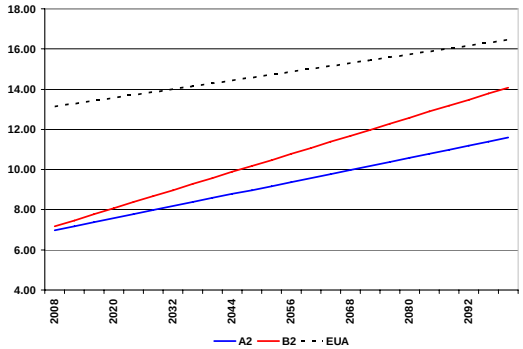
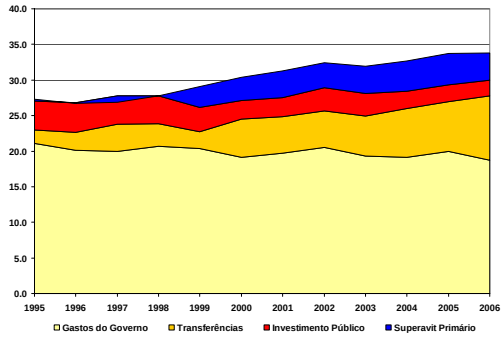


Figure 6 – Current allocation of government expenditures



The B2 scenario requires more expenditure on education than scenario A2. Given the usual behavior of Brazilian public accounts, this will come from increased tax burden. Therefore, B2 will deal with higher tax burden than A2. As displayed in Figure 7, in both cases there is a decline in the tax burden, approaching developed countries patterns. It is supposed that in the long-run Brazilian society will push for better government. The final parameter for the estimation of future scenarios refers to the conditional convergence coefficient, displayed in Figure 8. It captures the part not explained by the theory, and it is obtained by

the difference between the information observed in the data and what is measured using the theory. It thus reveals de degree of our ignorance about economic development. It is statistically estimated through regressions measuring the speed of approximation of the institutional residual between Brazil and the US. Figure 8 shows the projected convergence.

Figure 7 – Evolution of the tax burden (% of GDP)

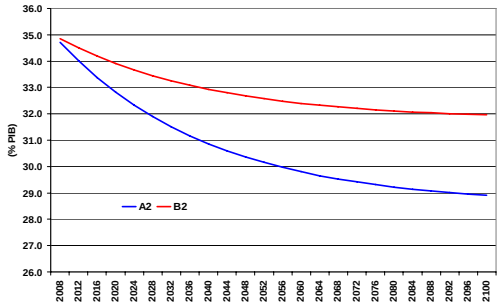
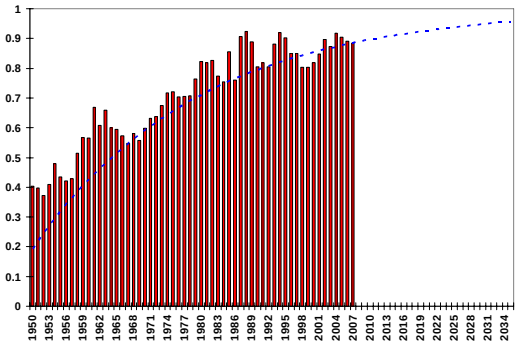


Figure 8 – Convergence to best practices



As a result, we have arrived at the numbers presented in Table 3. It is expected that the country will present a more stable macroeconomic situation, in relation to the last two decades, to be less vulnerable to external events, with low inflation and interest rates, and with a government more equilibrated in fiscal terms. However, growth rates are expected to be modest. This is due to low educational levels, in spite of the recent improvements, and to tax distortions and low government investment. Thus, a perverse combination of low levels of human capital with the wrong incentives to capital accumulation will harm productivity growth, which will in turn limit economic growth. The expected differences between A2 and B2 are not impressive, but growth will be higher in B2, mainly due to higher investments in education.

Table 3 – Macroeconomic scenarios

Macroeconomic Variables	2008	2035	
		A2	B2
GDP (US$ billions)	1,589	1,791	1,798
GDP growth (%, year	4.3	4.2	4.3
Inflation	4.5	4.4	4.4
Nominal interest rate	10.5	10.3	10.3
Real interest rate	5.7	5.6	5.6
Trade superavit (US$ billions)	14,7	-17,7	-18,5
Investment (% of GDP)	17.6	17.7	17.7
Net reserves (US$ billions)	200,0	223,0	223,0
Government primary debt (% of GDP)	-3.3	-2.5	-2.5
Government net debt (% of GDP)	39.4	31.3	31.2
Household consumption (% of DGP)	62.0	62.9	62.5
Government consumption (% pf GDP)	20.1	19.7	20.1

3. Sectoral scenarios

The above macroeconomic scenarios are the benchmarks for the construction of sectoral and regional scenarios[4]. We have constructed a multiregional Computable General

[4] In this paper only the sectoral scenarios are presented

Equilibrium model, which splits economic activity into 55 sectors and 558 regions. Both under A2 and B2, primary activities (agriculture, animal ranching, forestry, mining, etc.) increase their share in GDP, as well as tertiary activities (commerce and services), with manufacturing reducing its share. However, within these broad sectors, changing shares will be present. Since the economy will growth faster, although modestly, a scenario considering the present energy use will lead to increasing emissions, as Figure 9 presents, which are even higher in B2, since the economic growth is higher in this case. The expected level of per capita emissions in 2035 will be 13.7 tCO2, which is higher than the level of 11.7 in Europe, and close to the 20.4 of US in 2002. However, the economy becomes marginally cleaner, as Figure 10 indicates. The percentage growth in emissions resulting from GDP growth will decrease in time. This is the result of the changing sectoral composition of production, since sectors with lower emissions, comparatively, will increase their shares on GDP.

Figure 9 – Evolution of total emissions CHG (Cg CO2-equivalent)

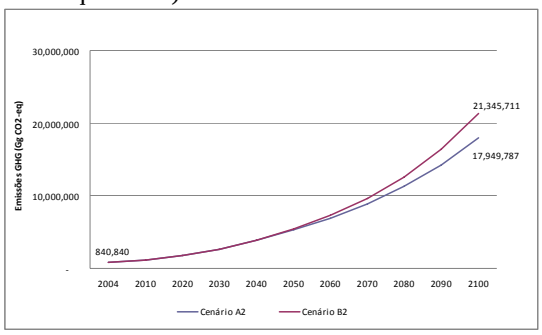
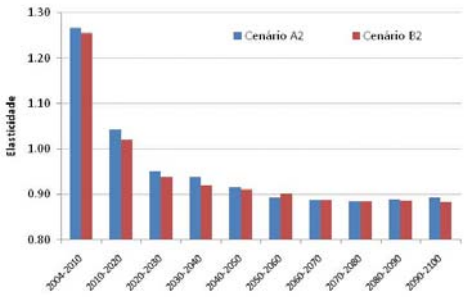


Figure 10 – Emission-elasticity of GDP growth



4. Energy scenarios

In terms of energy, we have incorporated new trends in energy intensity by sector, in order to adjust all sectoral projections. The most probable hypotheses about structural changes in the energetic matrix up to 2035 were incorporated. As for the presentation of the results, we consider two situations: a) trend scenarios, with no climate change, and a fixed energetic matrix (fixed energy intensity in every sector) – A2.1 and B2.1, and b) new scenarios incorporating trends in the utilization of energy in each sector – A2.3 and B2.3[5]. We have forced the final growth rates in A2.3 and B2.3 to be approximately the same as in A2.1 and B2.1. Therefore, we are not estimating the effect of energy on growth. Table 4 presents interesting information on the energy intensity by source. Considering all sources, intensity will drop more in the B2 scenario; for A2, there will be an increase from 2010 to 2035, but the final level will still be lower than the 2004 level (2004 = 100). As for the individual sources, growth (in relation to 2004) is present in sugar-cane bagass, vegetable coal and other sources only. In general, intensity will drop more in the B2 scenario.

[5] The study was developed by COPPE, Federal University of Rio de Janeiro, Programa de Planejamento Energético, within the original study from which this paper derives (www.economiadoclima.org.br). They have estimated an energy model for the final use of energy by sector.

Table 4 – Energy intensity by source, (thousand tep/R$2004; 2004 = 100)

	A2		B2	
	2010	**2035**	**2010**	**2005**
Oil and derived products + natural gas	87	88	87	77
Electricity	99	88	99	88
Mineral coal	93	91	93	93
Vegetal coal	95	123	96	125
Logging	91	46	92	46
Sugar-cane bagass	113	121	114	123
Ethanol	114	207	114	95
Others	94	112	95	109
Total	**94**	**96**	**94**	**87**

The new energy intensities and changing energy utilization in different sectors change the results of scenario a). Although the original project is concerned with the effects of climate changes, the results presented in this paper do not consider those impacts. However, the change in the energy intensities and energy use are in part related to the expected changes in energy utilization embedded in the energy model used. Therefore, we deal with a changing scenario within which some adaptation to the effects of climate change into the rates of return of each energy type (in each sector) is considered.

Figures 11 and 12 present the evolution of production in the sectors “Oil and gas production” and “Oil Refining”. The changing energy intensity will reduce growth in both sectors, as compared to the fixed-intensity situation: by the year 2100, oil production will drop between 21% and 15%, and Oil refining will fall between 25% and 34%. Therefore, it is expected that the oil-related sectors will present lower shares in the Brazilian economy, although, given the expected economic growth, their total production will growth.

Figure 11 – Evolution of Oil and Gas Production

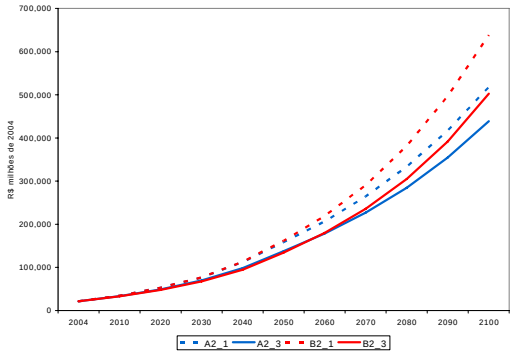
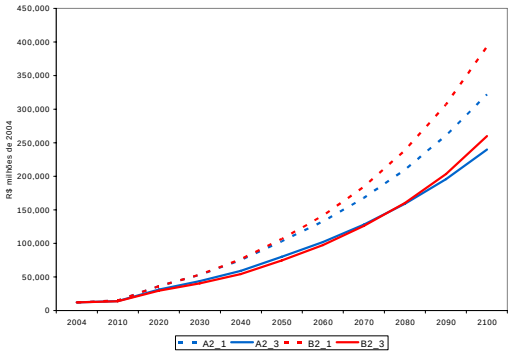
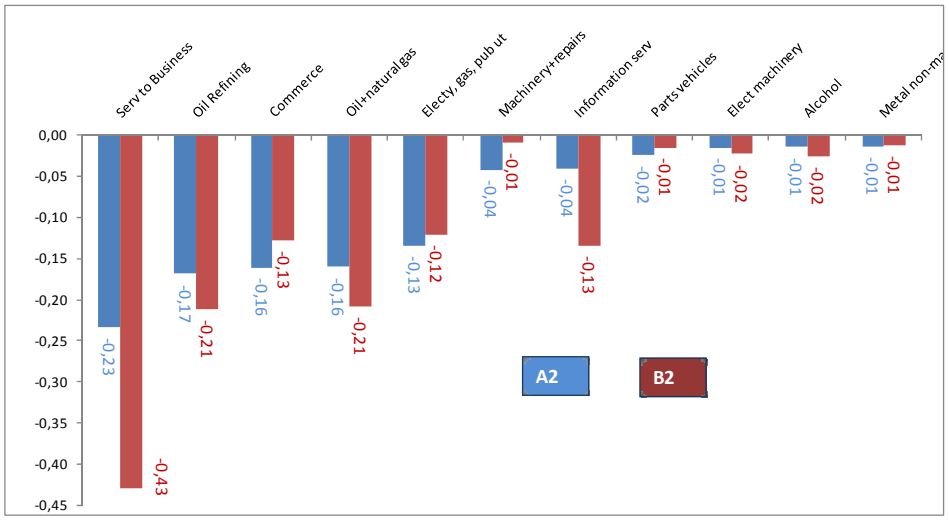


Figure 12 – Evolution of Oil Refining Production



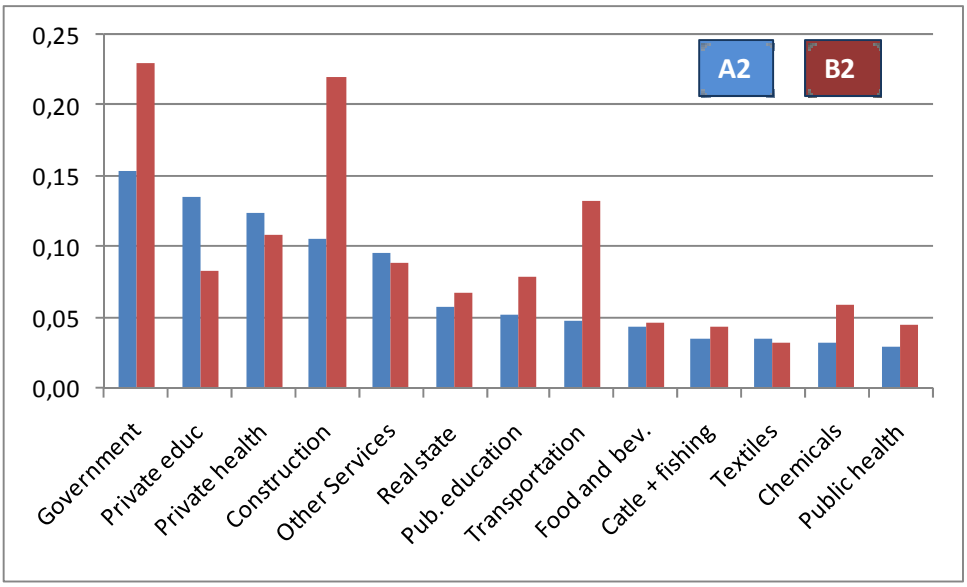
Introducing all these changes into the CGE model produce changes in the sectoral composition of production, which are displayed in Figures 13 and 14. The losing sectors are, in decreasing order of importance, services do business, oil refining, commerce, oil and natural gas, electricity, gas and public utilities, and so on. It is interesting to point out the loss in alcohol, due to adaptation in less use of vehicles. These losses are similar in A2 and B2, but they are generally higher in B2.

Figure 13 – Sectors losing participation in GDP due to adaptation in energy use



The gaining sectors displayed in Figure 14 are, in decreasing order, government, private education, private health, construction, other services, real state, public education, transportation and so on. There are some large differences between A2 in B2, such as in government, construction, and transportation, with larger positive impacts under B2.

Figure 14 – Sectors gaining participation in GDP due to adaptation in energy use



5. Final considerations

We have established scenarios for Brazilian economy for the period 2008-2035. We have used a Dynamic General Equilibrium model to estimate the macroeconomic scenario, and a multiregional Computable General Equilibrium model to compute the sectoral scenarios. Global scenarios for climate change were taken from the IPCC study, and their influences were used to calibrate the national scenarios. Under a more environment-friendly scenario (B2), the Brazilian economy will growth slightly faster, although still at lower annual rates. This faster growth will provoke increased emissions, as compared to the A2 scenario. In general, however, the structural changes forecast will make the Brazilian economy cleaner, in terms of shares.

As for energy, we have used initially the same use matrix as in 2008, and then have changed it to incorporate reaction of agents to relative rates of return of different energy sources, which already incorporates some adaptation to expected changes of economic agents' decisions in reaction to global climate change situations. On average, scenario B2 will be less energy-intensive than scenario A2.It is clear that oil production and oil refining will not growth as much after the incorporation of those aspects. Vegetable coal is expected to be more intensively used in the future energy matrix, as well as sugar-cane bagass. Ethanol will increase its share under global scenario A2, but that does not repeat under B2. Other sources, including nuclear and wind, are also expected to increase.

Further advancements in the study include the inclusion of other forms of adaptation, especially in agriculture and land use. Changes in consumption patterns are also important, and must be included in the calculations in the future.

6. References

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