Climate change impacts on agriculture and internal migrations in Brazil

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Joaquim Ferreira-Filho,

Mark Horridge

Centre of Policy Studies, Victoria University

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Address: Centre of Policy Studies, Victoria University, PO Box 14428, Melbourne, Victoria, 8001
home page: www.vu.edu.au/CoPS/ email: copsinfo@vu.edu.au Telephone +61 3 9919 1877

Abstract

Recent internal migration flows in Brazil differ from historical patterns observed since the seventies. In the past internal migration typically flowed from states in Northeast Brazil and Minas Gerais towards the richer states of São Paulo and Rio de Janeiro. According to Brito and Carvalho (2006) between 1960 and 1990 about 8.1 million people left the Northeast and 3.8 million left Minas Gerais.

This was the “normal” internal migration pattern in Brazil until the eighties, when, according to Brito and Carvalho (2006), a succession of economic crises and expansion of the agricultural frontiers changed the picture. Actually, during the nineties emigration from the Northeast region slowed down considerably; the region became a net recipient of population in recent years. At the same time, the Southeast states of São Paulo and Rio de Janeiro, the main destination for migrants until the end of the eighties, have recently lost population. Some of the migrants leaving the Southeast return to the Northeast, but many go to the dynamic new agricultural Center-west regions.

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CLIMATE CHANGE IMPACTS ON AGRICULTURE AND INTERNAL MIGRATIONS IN BRAZIL

Joaquim Bento de Souza Ferreira Filho[1]
Mark Horridge[2]

1 Introduction

Recent internal migration flows in Brazil differ from historical patterns observed since the seventies. In the past internal migration typically flowed from states in Northeast Brazil and Minas Gerais towards the richer states of São Paulo and Rio de Janeiro. According to Brito and Carvalho (2006) between 1960 and 1990 about 8.1 million people left the Northeast and 3.8 million left Minas Gerais.

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2 Objective

The objective of this paper is to assess the potential impacts on internal migration in Brazil of different climate change scenarios that impact on agriculture. Of particular interest in the analysis will be the effects on labor demand, both in the agricultural sector and in the whole economy, and its role in the inter-regional patterns of population flows. The analysis will be conducted with the aid of a dynamic general equilibrium model of Brazil, the TERM-MIG model, to be described below.

3 Internal migration in Brazil: recent patterns

The Pesquisa Nacional por Amostra de Domicílios – PNAD (National Household Survey) is the data source for the migration data in this study. The PNADs are available since the seventies, and are a comprehensive household survey, usually regarded as being of very good quality, and the main data source for many different studies. Among the many questions surveyed by PNAD are the person’s region of origin, and where each person was living in previous years. These questions allow us to identify migrants.

There is no established definition of a migrant in the literature, with different authors using different definitions, depending on their interest. For the sake of describing the migration flows and analyzing the influence that different definitions can have on them, migration flows were collected according to different definitions for the period 2001-2007, from PNAD micro data.

The criterion to define each person’s migration status was initially to compare the actual region where the person is living with the region of birth. The second step was to check if the period for which the person is living in the different region would be sufficient to define him as a “migrant”.

[1] Address: ESALQ/USP. Departamento de Economia, Administração e Sociologia Rural. Av. Pádua Dias, 11. Piracicaba, SP. Brazil. CEP – 13418-900. Email: jbsferre@esalq.usp.br. The author is grateful to CAPES for partial funding of his participation in this event.
[2] Centre of Policy Studies – COPS, Victoria University, Melbourne, Australia.

Many different criteria were used, and the total number of migrants according to each definition can be seen in Table 1. In the table the criteria used to define a migrant were: a person living in a region other than region of birth for 2 years, 3 years or 5 years.

Table 1: Total internal migration in Brazil, different definitions.

Number of years living in the region	2001 20	02 20	03 20	04	2005 20	06 20	07
2	1183171	1528940 1	425925 1	433473	1502439 1	384481 1	466653
3	1169798	1322344 1	478194 1	386877	1505782 1	412310 1	493893
5 1251173		1411385	1362150	1219948	1555577 1407	262	996058

Table 1 shows that the number of migrants is fairly stable across different definitions. The Brazilian literature on migration usually takes the 5 years time span as the main criterion to define migration (see, for example, Braga, 2006; and Brito et al, 2006). We will also use this criterion, since it excludes those moving temporarily, like students. The net regional flows[3] (in-migration minus out-migration) according to that criterion can be seen in Table 2. There, negative numbers mean population outflows, and positive numbers mean population inflows. The same information is also presented in Figure 1.

[3] The model database includes a full bilateral table of migration flows, for each year and labor type.

Table 2: Net migration flows in Brazil, by region. Number of people.

NETFLOW	Y2001 Y2	002 Y2	003	Y2004 Y	2005 Y2	006 Y2	007
1 Rondonia	-7,655 -11,	319	4,210	3,054	-13,470	-2,455	-7,045
2 Acre	4,467	-4,658	1,329 3,	060	-185 3,20	4	-2,147
3 Amazonas	917	5,662	4,199 4,	763	-736 2,82	3 9,44	9
4 Roraima	9,192	-541	6,500 1	,886 6	,027 9	,363	10,166
5 Para	-30,329 -30,	750 -26,	249	-16,099 -2	6,218	-5,178	-14,963
6 Amapa	-1,016	5,401	4,932	-3,118 5,79	4 1,33	9 1,83	1
7 Tocantins	-3,786 -5	,299	-5,402	4,901	-16,399	-8,312	10,412
8 Maranhao	300 -14,	029	5,693	-6,387	24,701	-17,745	-757
9 Piaui	-20,005 9	,698	4,708	6,656	888	12,062	-1,033
10 Ceara	39,182	-3,052	23,404 1	6,112	6,004 1	7,996 1	4,810
11 RGNorte	-3,620	1,977	11,709	3,190	17,922 -2	,972 -7	,551
12 Paraiba	-10,000	-21,442	-4,206 -4,	769 -1,79	4	6,262	-11,018
13 Pernambuco	-22,765 -13,	156 -33,	868	-5,171 4,21	8	-13,901	1,180
14 Alagoas	-20,798	-35,465	-7,607 -20,	607	-5,650 -16,6	91	-2,774
15 Sergipe	-6,097	-14,782	-7,419	3,614 -7	,826 -6	,973	1,051
16 Bahia	-70,554 -10,	753 -21,	421	-9,667 -	489	4,989	-16,417
17 MinasG	40,878	5,319	25,060 1	9,523 2	3,432 4	8,284	-21,769
18 EspSanto	1,285 5	,521	-10,552	7,078	-6,177	18,447	4,768
19 RioJaneiro	-20,825 4	,328	-3,520	9,501	-11,512	-30,143	-9,074
20 SaoPaulo	81,767	87,059	-11,967 -3	5,696 -4	9,215 -7	9,661	-19,294
21 Parana	-17,712 2	7,792	16,161	-4,461	-3,880	7,285	-9,495
22 StaCatari	12,142	-8,121	-5,939	3,825	14,398 2	7,871 4	6,939
23 RGSul	-5,384 3	,134	4,886	-6,913	15,578	-2,618	-11,613
24 MtGrSul	-4,213 -1	4,450	-1,154	7,292	-5,733	-7,019	341
25 MtGrosso	17,597	18,240	11,349	12,520 9	,309 1	1,793 2	,854
26 Goias	44,324 3	2,256	34,947	35,175 4	6,915 3	8,843 1	0,945
27 DF	-7,292	-18,570	-19,783 -2	9,262 -2	5,902 -1	6,893	20,204

OBS: migrant defined as someone living in a region different from its origin for 5 years.

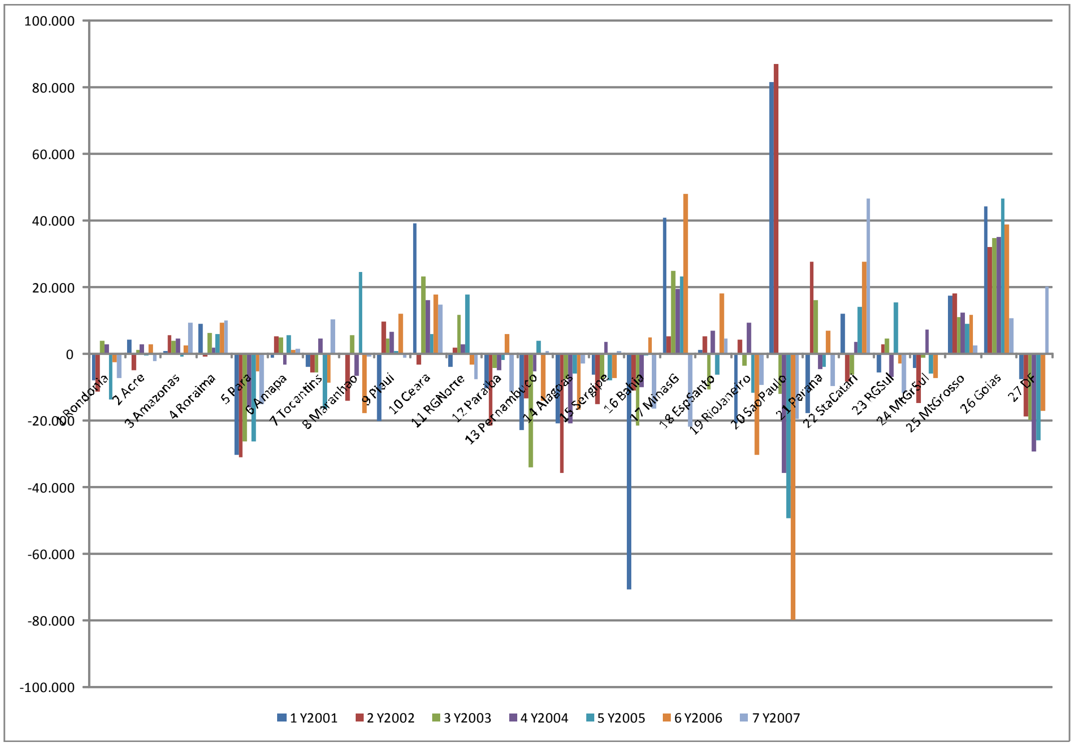

Figure 1: Net migration flows in Brazil, by region. Number of people.

Table 2 and Figure 1 illustrate the point mentioned before regarding the recent reversal of internal migration flows. The important Southeastern states of São Paulo and Rio de Janeiro, which were poles of attraction in the past, now face population outflow. The same happens to the Brazilian Federal District, to the Pará state (in the Amazon region), and to the Southern states with the exception of Santa Catarina. Two scantily populated Northern states, Roraima and Amapá, are consistently gaining population. However, Northeast Brazil, which, together with Minas Gerais, was the main supplier of migrants now shows mixed behaviour. Ceará state in this region is consistently gaining population, and the same seems to be happening to the smaller states of Piaui and Rio Grande do Norte. And, finally, Minas Gerais gains population in every year shown except 2007.

Figure 2: Brazilian states and macro regions

The geographical location of the Brazilian states listed in Table 2 can be seen in Figure 2, where the macro regions (official definition) are also shown:

- North region: states of Acre, Amazonas, Roraima, Amapá, Pará and Tocantins;
- Northeast region: Maranhão, Ceará, Piaui, Rio Grande do Norte, Paraíba, Alagoas, Sergipe and Bahia;
- Southeast region: Espírito Santo, Rio de Janeiro, Minas Gerais and São Paulo;
- South region: Paraná, Santa Catarina and Rio Grande do Sul;
- Center-west region: Mato Grosso, Mato Grosso do Sul, Goiás and Brasilia (the Federal District).

As may be seen from the data, the population flows in Brazil presently follow a completely different pattern than was observed in the seventies and eighties, when there was an intense flow from the Northeast region towards the Southeast region. During that time Brazil's model of economic development entailed a transfer of population from rural areas to the cities, and from the Northeast regions to the Southeast, mainly São Paulo and Rio de Janeiro. The same phenomenon is noted by Brito et al (2006).

More recent data, however, show that São Paulo and Rio de Janeiro are the most important source of population movement to other states. The Federal District (DF -- basically Brasilia, the capital) is also losing population, with a net migration outflow from 2001 (Table 2); yet this outflow is less in 2007, probably due to the recent strong increase in federal spending. Maranhão, a poor state in the Northeast, also shows negative population flows until 2007, when positive figures were registered.

It’s interesting to notice that some poor Northeast states have consistently received positive migration flows since 2001, as is the case for Ceara, Rio Grande do Norte (RGNorte), Paraiba and Pernambuco. This is an inversion in the migration flows if compared to the seventies. Apparently this is due to a combination of urban congestion in the main cities (São Paulo and Rio de Janeiro), as well as new investments in Northeast Brazil. Another hypothesis to be considered is the greater incidence of the Bolsa Familia Program[4] in the northeast region.

The Center-west region (Mato Grosso, Mato Grosso do Sul and Goias states) is also attracting population, The economies of these states, the main grain producing regions of Brazil, are driven by soybean, corn and livestock production. The abundant grain supply and more reliable electric power have also fostered growth in the food industry.

The data suggest that population has been flowing consistently from the relatively richer Southeast Brazil towards the Northeast and the Center-west regions. Those destinations are, however, regions that will likely be the most severely hit by the effects of climate change on agriculture, as some recent scenarios analyzed by Embrapa (the Brazilian Federal Agricultural Research Institution) show. An eventual reversal of those flows would bring important policy implications for the regional governments in the Southeast regions.

Considering Brazil's vast inland thinly-peopled regions, the current migration patterns described above imply a beneficial decentralization of population – which may be threatened by the effects of climate change on agriculture. Pinto and Assad (2008) and Deconto (2008) provide a translation for Brazil of several IPCC scenarios for climate change in agriculture. These scenarios include estimates of losses in both agricultural productivity and useable land for various Brazilian regions and crops. In general, the scenarios point to a loss in productivity and agricultural land availability in the regions which are currently net population recipients, *potentially reversing current internal migration flows*. These are the scenarios to be simulated in this paper, as described below.

4 Methodology

This paper explores in more detail the implications of climate change and its impacts on agriculture for internal migration flows in Brazil, with the aid of a detailed dynamic General Equilibrium Model of Brazil which has its theoretical foundations in previous work of Ferreira Filho and Horridge (2004) and Ferreira Filho and Horridge (2010). It is an inter-regional, bottom-up, annual recursive dynamic model with detailed regional representation, distinguishing up to 27 Brazilian regions, 38 sectors, 10 household types and 10 labor grades, and has a migration module which models gross bilateral regional migration flows. The core database is based on the 2005 Brazilian Input-Output model, as presented in Ferreira Filho (2010). The migration database is also based on the 2005 year, as explained before, and is obtained from the Brazilian Household Survey (PNAD).

The recursive dynamics included in the model consist basically of three mechanisms: (i) a stock-flow relation between investment and capital stock, which assumes a 1-year gestation lag; (ii) a positive relation between investment and the rate of profit; and (iii) a relation between wage growth and regional labor supply. With these three mechanisms it's possible to construct a plausible base forecast for the future, and a second, policy, forecast – different only because some policy instruments are shocked to different values from the base (eg, the climate change scenarios). This difference can be interpreted as the effect of the policy change. The model is run with the aid of RunDynam, a program to solve recursive-dynamic CGE models[5].

Two scenarios will be analyzed: the IPCC A2 scenario for 2020, and the B2 scenario for 2070. The A2 scenario is the worst scenario for 2020, while the B2 scenario is the best scenario for 2070, meaning by "best" a scenario that allows enough time for adaptation measures. The shocks were based on the work of Moraes (2010), which used a detailed geographical information system production map at county level in Brazil and on the agricultural productivity and land losses provided by Pinto and

[4] The Bolsa Familia is the major direct income transfer program from the Brazilian Federal Government.

Assad (2008) and Deconto (2008) to calculate the state level agricultural productivity and land loss shocks. The detailed shocks to be implemented will be described later in this paper.

The use of a dynamic model involves two prior steps: an initial historical run, where the model is forced to reproduce the known behaviour of some aggregated variables over a set of previous years, and the definition of a reference path for the economy in the future, in relation to which the policy scenarios will be reported, The historical simulation has the purpose of updating the original 2005 database with recent developments in the economy. In this paper, the historical simulation forced the model to reproduce macro trends for the period 2005 to 2008 (last available year of the Brazilian National Accounts) for the variables described in Table 3.

Table 3: Historical simulation shocks, Percentage changes,

Variable	**Observed annual average rate of growth (%)**
Population	Regional values by IBGE
Land productivity	1,0
Real government spending	2,9
Real GDP	4,6
Real household consumption	5,8
Real exports	4,9
Real investment	9,7
GDP deflator	7,0

For the reference scenario, the regional population was updated with information from Instituto Brasileiro de Geografia e Estatística (IBGE), which presents information on observed population growth at regional level until the present, and with projections of population growth by region until 2030. The regional growth rate of population in 2030 was used for the subsequent annual projections until 2070. This information can be seen in the Appendix.

The baseline path was created by projecting the economy forward until 2070, roughly following the observed pattern for some important economic variables, as shown in Table 4. The shocks were applied, and the remaining variables adjusted endogenously to accommodate the proposed shocks, creating a reference baseline until 2070, in relation to which the results will be reported. The policy shocks, then, will generate deviations in relation to the proposed baseline.

Table 4: Baseline projections, Percentage change,

Variable	Projected annual average rate of growth (%)
Export demand shifter	3,0
Population	Regional values by IBGE
Labor productivity increase	1,5
Land productivity	1,0
Real government expenditures	3,0
GDP deflator	5,0

[5] RunDynam is described at: www.copsmodels.com/gprdyn.htm

Although the original model database distinguishes 27 regions of Brazil, we aggregated these to 13 broader zones. This aggregation eases presentation and reduces computing time[6]. The regions were aggregated according to similarity, both in terms of general economic aspects as well as recent migration characteristics, while trying to keep enough regional detail. The mapping from original to new regions is shown in Table 5.

Table 5: Regional aggregation.

Original region	Aggregated region	Or iginal region	Aggregated region
Rondonia (N)	RestNO	Sergipe (NE)	RestNE
Acre (N)	RestNO	Bahia (NE)	Bahia
Amazonas (N)	RestNO	MinasG (SE)	MinasG
Roraima (N)	RorAmap	EspSanto (SE)	RioJEspS
Para (N)	RestNO	RioJaneiro (SE)	RioJEspS
Amapa (N)	RorAmap	SaoPaulo (SE)	SaoPaulo
Tocantins (N)	RestNO	Parana (S)	Parana
Maranhao (N)	MarPiaui	StaCatari (S)	SCatRioS
Piaui (NE)	MarPiaui	RGSul (S)	SCatRioS
Ceara (NE)	RestNE	MtGrSul (CW)	MatoGSul
RGNorte (NE)	RestNE	MtGrosso (CW)	RestCO
Paraiba (NE)	RestNE	Goias (CW)	RestCO
Pernambuco (NE)	PernAlag	DF (CW)	RestCO
Alagoas (NE)	PernAlag		

Macro regions: N – North; NE – Northeast; SE – Southeast; S – South; CW – Center west,

5 The scenarios to be simulated

As stated before, two scenarios will be simulated in this paper: the IPCC A2 (worse) scenario for 2020 and the B2 (best) scenario for 2070 (Moraes, 2010). The shocks to be applied to the model are described in Table 6, Table 8, and Table 9 below.

[6] Yamamoto (2004) 10 estimates that a 10 percent increase in the number of regions results in a 29 percent increase in simulation time and uses 14 percent more memory.

Table 6: Shocks to production, year 2020 (% variation)

Region R	ice	Corn	Sugarcane	Soybean	Cassava	Cotton	Coffee	Other ag
1 RorAmap	0 0		0	0	-49,4 0 0			0
2 RestNO	-4,2	-1,7	0,4	-17,2 -1,	9	0	-80 -0,1	
3 MarPiaui	-39,3	-30,8	-1,1	-80 -2,	5 -4,4		-80	-11,3
4 PernAlag	-80 -67,7		-5	-79,4 -	63,4 -62,2		-80	-7
5 Bahia	-3,5	-13,4	-5	-0,4 -18		0	-80 -5,4	
6 RestNE	-80	-60,7	-4,3	-79,4	-22,1 -80	-80		-18,6
7 MinasG	-4	-1,4	5	-3,2	-11,6 -7		-3,5 -2	
8 RioJEspS	0 -0	,8	2,3	0	0	0	-4,3 -0	,8
9 SaoPaulo	0	-2	5,5	-7	0	0	-19,2	-0,2
10 Parana	0 0		7	-45,3	-4,9 0 0			0
11 SCatRioS	0 0		0	-30,6	-20,2 0 0			0
12 MatoGSul	0	-14,6 6		-60 0		0	-80 0	
13 RestCO	-1,9	-2,6 6		-25,2 0		0	-80	-0,4

Table 7: Shock to land availability, year 2020 (% variation)

Shocp Ri	ce	Corn	Soybean	Cassava	Cotton	Coffee	Other ag
1 RorAmap	0	0 0		-49,4	0 0 0		
2 RestNO	-5,6	-2	-17,1 -1,	8	0	-80 -0,	1
3 MarPiaui	-40,4	-34,9	-80	-2,8	-14,7	-80	-9
4 PernAlag	-80	-68,5 -7	9,4 -6	1,5	-62,2	-80	-7,5
5 Bahia	-2,9	-32,3 -0	,4	-19,3	0	-80 -4	,6
6 RestNE	-80	-60,7 -7	9,4 -2	1,1	-80	-80 -2	2,4
7 MinasG	-4,9	-3,9 -3,	1 -8,	7	-16,6	-2 -3,	1
8 RioJEspS	0	-1 0 0			0	-6,4	-0,7
9 SaoPaulo	0	-2 -7	,4	0	0	-27 -0	,1
10 Parana	0	0	-36,8	-5,8	0	2,4	0
11 SCatRioS	0	0 -3	6,2 -2	3,5	0	0	0
12 MatoGSul	0	-14,6	-64,2 0		0	-80 0	
13 RestCO	-1,9	-3,3	-23,3	0	0	-80	-0,6

Table 8: Shocks to production, year 2070 (% variation)

Shock R	ice	Corn	Sugarcane	Soybean	Cassava	Cotton	Coffee	Other ag
1 RorAmap	0 0 0 0				-49,4 0		0	0
2 RestNO	-5,2	-3,3	-0,2	-20,2 -0,	6	0	-80 -0,2	
3 MarPiaui	-47,4	-50,3	-2,1	-80	-2,5	-14,2	-80	-23,6
4 PernAlag	-80 -71,3		-10 -79,4	-	63,4	-62,2	-80	-9,4
5 Bahia	-3,5	-36,2	-10 -0,4		-19,6	0	-80 -6,3	
6 RestNE	-80 -68,5		-8,6 -79,4	-	22,1	-80	-80 -18,	6
7 MinasG	-4	-1,4	-2	-33 -1,	1	-7	-16,6 -2,6	
8 RioJEspS	0	-1,6	-3,6 0		0 0		-66,6	-1,1
9 SaoPaulo	0 -7,2		-3,5	-32,1	0	0	-72,2 -0,3	
10 Parana	0 0		-4	-76,3	-6,8 0		-14,7	0
11 SCatRioS	0 0	6		-64,7	-3,8 0		0	0
12 MatoGSul	0	-17	-1,5	-61,5 0		0	-80 0	
13 RestCO	-1,9	-2,6	-1,5 -2	6,8	0	0	-80	-0,6

Table 9: Shocks to land availability, year 2070 (% variation)

Shocw Ri	ce	Corn	Soybean	Cassava	Cotton	Coffee	Other ag
1 RorAmap	0	0 0		-49,4	0 0 0		
2 RestNO	-7,3	-4,1	-18,1 -1	,6	0	-80 -0	,2
3 MarPiaui	-47	-47 -8	0	-2,8	-14,7 -8	0	-23,4
4 PernAlag	-80	-80 -79,4		-61,5 -62,	2	-80	-11,1
5 Bahia	-2,9	-74,4	-0,4	-21	0	-80	-5,6
6 RestNE	-80	-68,8	-79,4	-21,1 -	80 -80		-22,4
7 MinasG	-4,9	-3,9 -30,7		-0,8 -16,	6	-14,5	-3,2
8 RioJEspS	0	-1,8 0	0		0	-67	-0,9
9 SaoPaulo	0	-8	-35,9	0	0	-73,1	-0,3
10 Parana	0	0	-77,1	-8,1	0	-15,1	0
11 SCatRioS	0	0	-67,1	-5,5	0 0 0		
12 MatoGSul	0	-17,5	-65,8 0		0	-80 0	
13 RestCO	-1,9	-3,3	-24,9	0	0	-80	-1,1

The shocks in the tables are percentage changes in production and land availability, by each agricultural product and by region. The values are the total (cumulative) percent variation up to the respective year. To apply the shocks to the dynamic model, the cumulative changes were converted into annual changes, such that the desired accumulated change in either 2020 or 2070 was achieved. The shocks for the 2020 scenario were applied from 2015 until 2025, while the shocks for the 2070 scenario were applied from 2026 until 2065. The shocks, of course, were calculated so that the total final shock at 2070 is the aggregation of the year shocks.

This mixing of two scenarios was necessary in order to try to describe a "path" of adjustment, based on the resulting scenario in the final years of each period. This is important since some activities change their behavior in passing from one scenario to another. This is the case for sugar cane, where there is an increase in productivity in the first (A2, 2020) scenario, due to the increase in temperature and CO2 concentration, which would be beneficial for the crop. This effect vanishes in the longer run, when temperatures and CO2 concentration continue to increase, exceeding the optimal level for sugar cane production. The model would be missing this effect if only a year shock based on the final 2070 scenario were used. The same effect happens with land availability for Coffee in Parana under the 2020 scenario.

And, finally, it's important to put the size of those production shocks into perspective. The share of agriculture in each state regional GDP is very different across Brazilian states, which combines with the size of the particular shocks to imply different regional importance. This relative importance can be inferred from Figure 3 below.

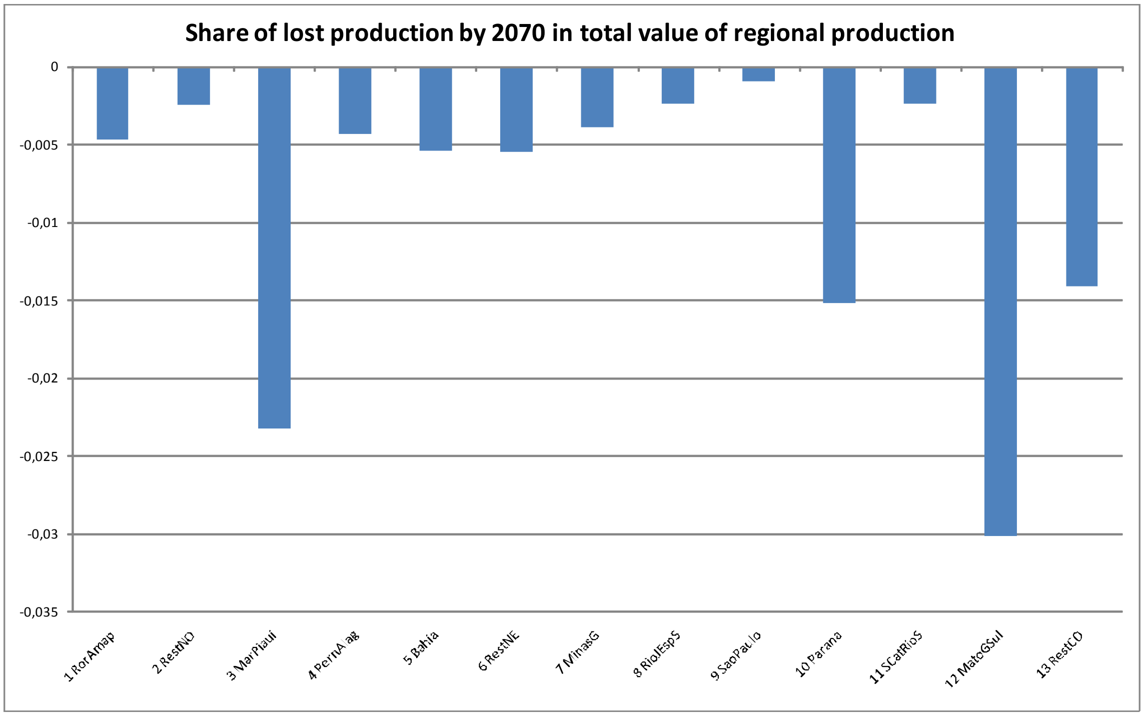

Figure 3. Share of lost agricultural production in total regional value of production.

Figure 3 shows the share of agricultural lost production (in the 2070 scenario) in total regional value of production in the base year database. The losses are not expected to be very high, even in the worst cases: MarPiaui (Northeast region) and MatoGSul (Center-west) regions. The losses amount to a 2.5% fall in total value of production in MarPiaui and around 3% for MatoGSul. So these shocks do not involve a large share of production value, when considering the direct impact only. The total effects, of course, are different, due to the economic linkages between primary agriculture and the rest of the economy, especially the food industry.

6 General Results

Considering the 65 years time involved in the analysis, we favor a graphical presentation of results, starting from the macro results of Figure 4.

The data in the figure show the percentage differences until 2070 between the projected economy base line and the policy simulation. It can be seen that the main macro variables fall, but the effects are not very strong. The accumulated fall in real GDP in 2070 would amount to 0.82%. Real investment in the economy would fall by around 0.5%, a result that oscillates during the adjustment period. Aggregated exports (volume) experience a stronger fall in the simulation, around 2%. This is not surprising if one takes into account the relative large share of food in total exports. These results, however, are strongly concentrated in coffee and soybeans, as will be discussed later.

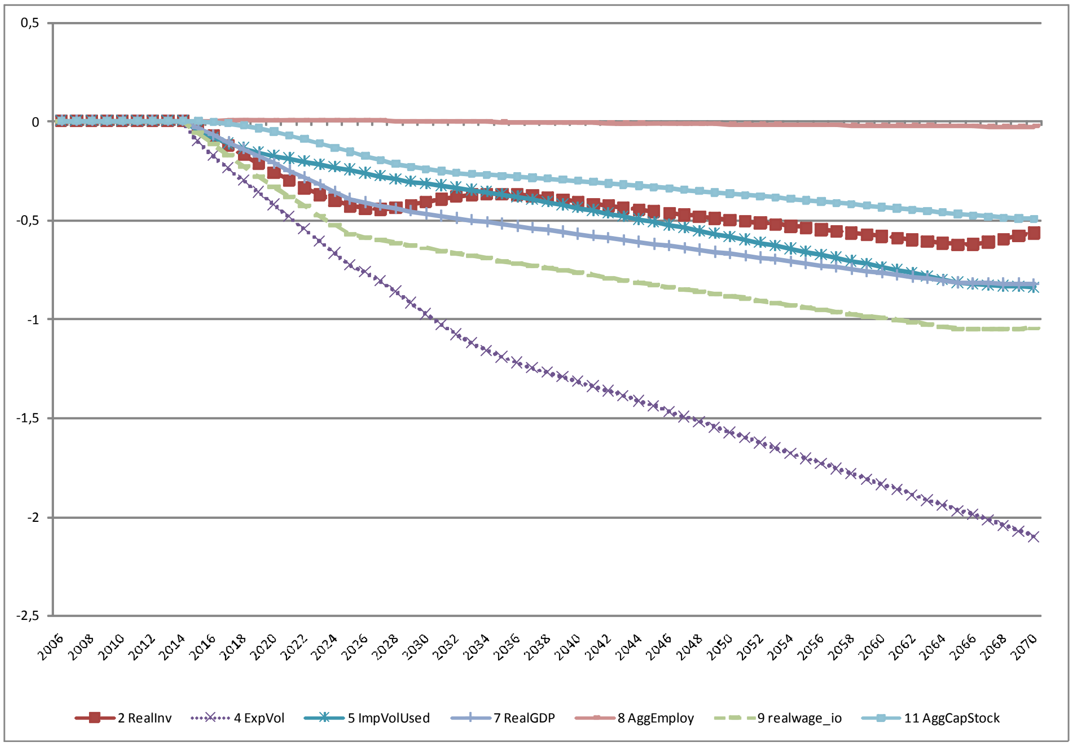

Figure 4: Macro results. Deviation from the baseline (Percentage change, accumulated).

The model predicts only a slight fall in total employment[7] (compared to the base line). The results of the climate change scenarios on the agricultural activities directly affected by the scenarios can be seen in Figure 5. As discussed earlier, sugar cane (and related activities, like ethanol) benefit from small increases in temperature and CO2 in the 2020 scenario – the effect lasts until 2047. Sugar cane production would increase by around 4.65% compared to the baseline in 2025.

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[7] Essentially, national employment is exogenous, and the same in both policy and base simulations. Regional employment varies through time through (a) natural population growth and (b) wage-driven inter-regional migration. Of course (b) washes out, nationally. However, there is a tiny and subtle effect on national workforce size: fecundity varies by region, and the migrating worker becomes as fruitful as his new neighbors. So if a fertile region attracts more workers, national employment will rise.

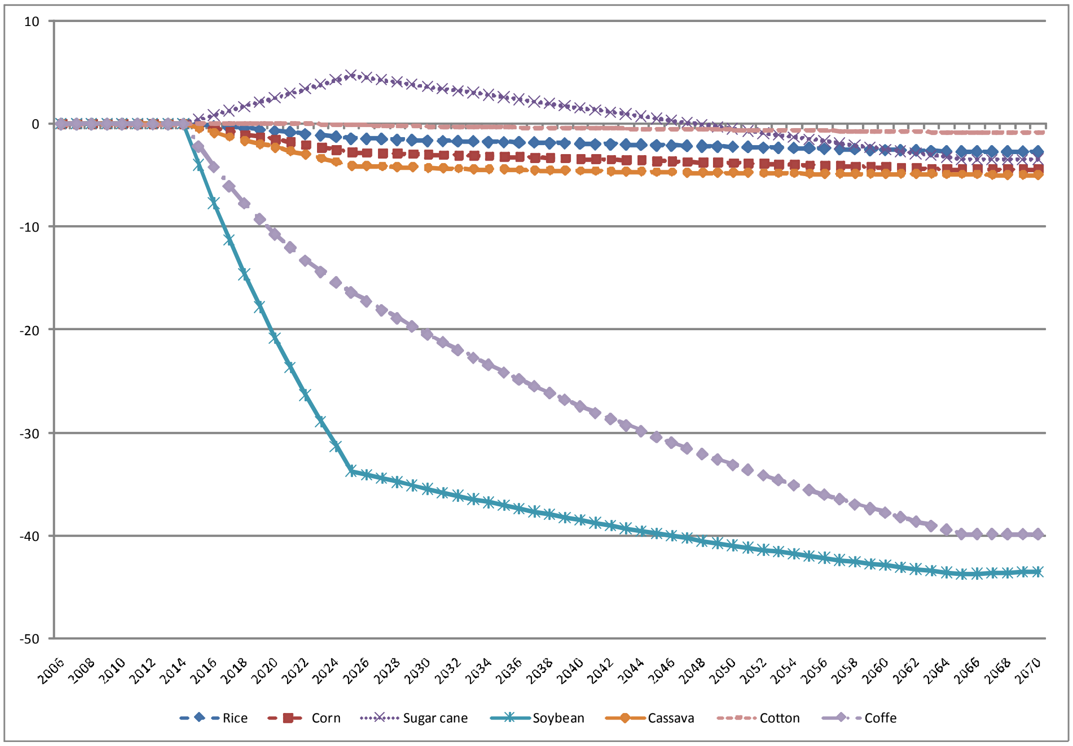

Figure 5: Agricultural production variation (deviation from base line, %).

Figure 5 shows too that soybean and coffee would be the two activities most affected by the scenarios. This is what causes the fall in exports mentioned before — these are important export crops. These crops are regionally concentrated in Brazil, leading to differentiated regional results.

The regional variation in real GDP can be seen in Figure 6. The state which is worst affected by the agricultural climate change scenario is Mato Grosso do Sul (-4.13%), a state in the Center-West region which relies heavily on soybean production (4.6% of total value of production in the state), and in which the predicted shocks to soybean productivity are particularly severe. As shown in Table 6 the shock to soybean productivity in the state would be -60% for the 2020 scenario. The other Center-west regions (RestCO) where soybean production is even more important (representing 4.9% of total regional production) would face a much smaller productivity shock (-25.2%), with a consequent smaller fall in GDP (-2.66% at the end of the period).

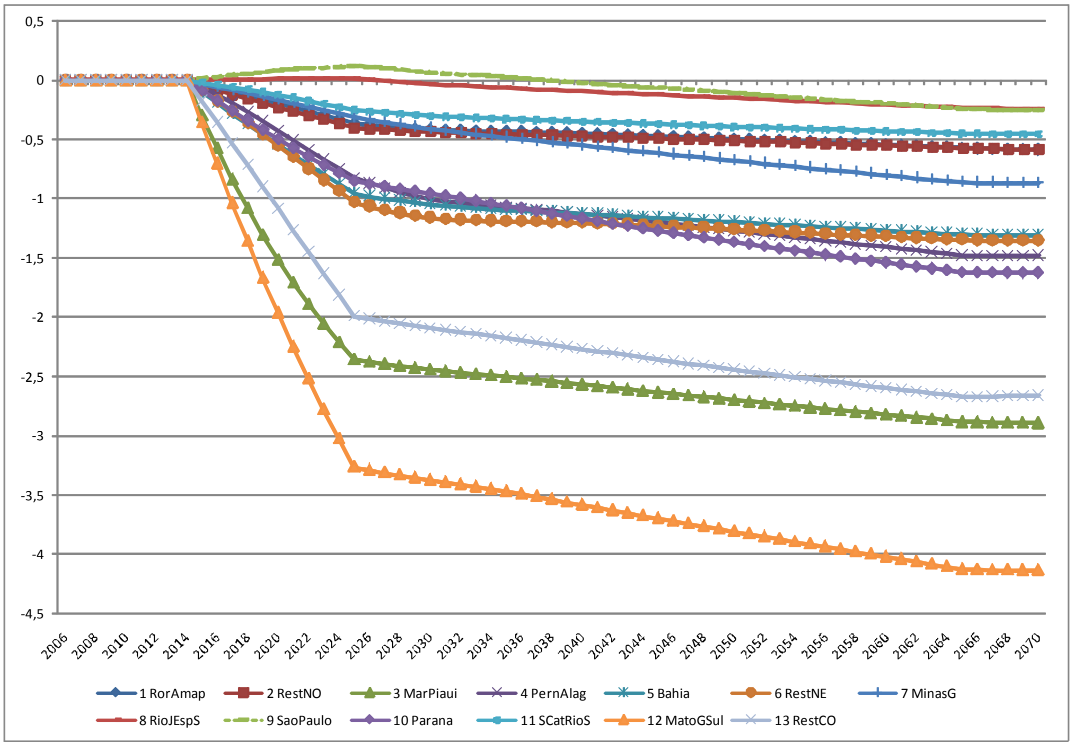

Figure 6: Regional real GDP variation (deviation from base line, %).

The above-mentioned result is very interesting, since the Northeast region is usually regarded as the one to lose the most from climate change in Brazil. This region, of course, would also be affected by the scenarios, but results are mixed among the region's states. The region comprising Maranhão and Piaui states (MarPiaui) would be the one more severely affected, losing about 2.9% of its real GDP in the long run. The other Northeast regions (PernAlag, Bahia, and RestNE) would be less affected, losing around 1.5% of real GDP.

It can be seen again that São Paulo state tends to benefit during the first period scenario, due to the increase in output of sugar cane and related products (ethanol and sugar). This is only a slight effect, though, which would peak in 2025 with a 0.12% in state GDP in relation to the baseline. The RioJEspS (Rio de Janeiro and Espirito Santo) region would also gain slightly in this period. And finally, the states in the North region (RorAmap, and RestNO, which includes Amazon) also face a small GDP decrease.

Notice that the change in regional employment does not necessarily follow GDP, since the regional production composition is different, and so is the labor demand by different activities in different regions. This can be seen in Figure 7.

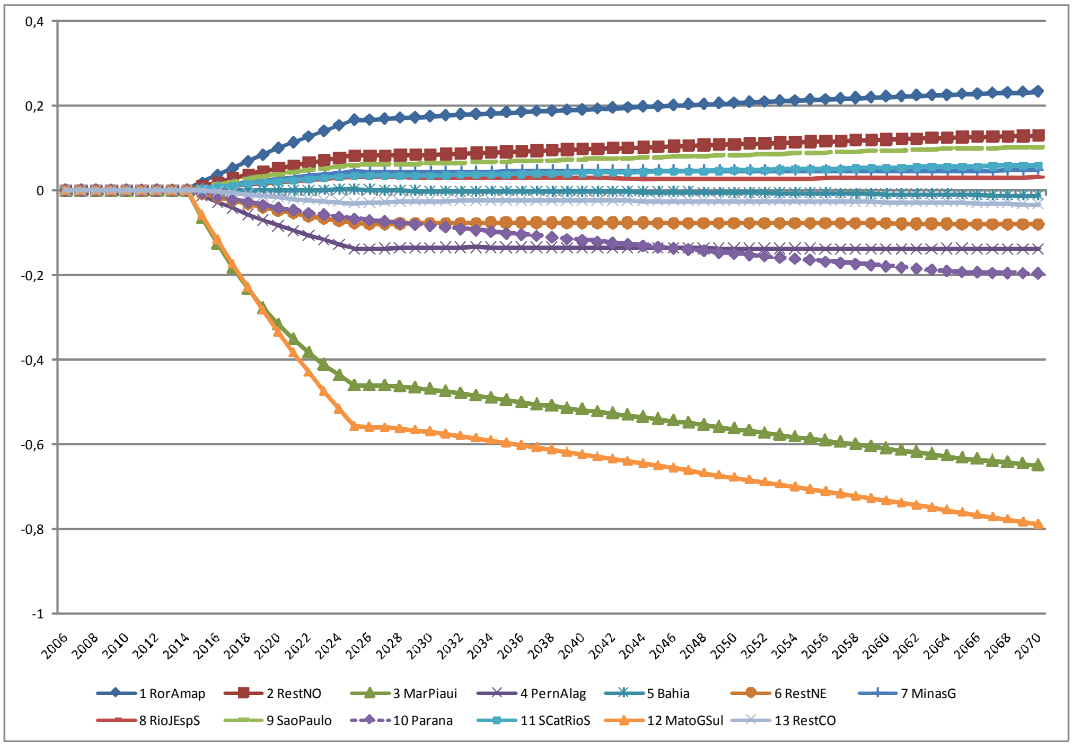

Figure 7: Regional employment variation (deviation from base line, %).

It was seen before that Mato Grosso do Sul and MarPiaui would lose the most, in terms of GDP, from the implemented scenarios. This is still the case in terms of employment: model results points to a 0.8% loss of employment in Mato Grosso do Sul and a 0.65% loss in MarPiaui. The other regions in Center-west Brazil show only a slight decline in employment. São Paulo shows a continuous increase in total employment even after 2025, when the sugar cane effect peaked. The most interesting result here, however, is the increase in employment for the Northern regions (RorAmap and RestNO). These states faced GDP losses, but gain in employment. This has to do with migration flows, to be discussed later, and could have important policy implications.

7 Migration results

The general results presented above constitute the background against which the migration results, the main objective of this paper, should be interpreted. In the model, migration is driven by the change in regional real wages: the labor force tends to move towards the regions where real wages are increasing, and vice-versa.

The model distinguishes 10 different occupations or labor types, each with region-specific wage rates. Employment of each occupation is supposed to increase in the baseline at the same rate as regional population, for which official estimates of the Brazilian Statistical Agency (IBGE) were used, as explained before. The demand for those different worker types, however, will depend on the labor mix used in production, which varies by sector and region. In what follows, the movement of total labor across regions is presented, and later the occupational composition will be discussed.

It was seen before that net inter-regional migration in Brazil flows presently from the richer Southeast region to the Center-west, some Northeast and some Northern states. Our climate change scenario, however, falls heavily on the Northeast, as seen above. The model results for the effects on migration of these impacts can be seen in Figure 8, which shows the variation in migration, by region of origin, caused by the policy scenario.

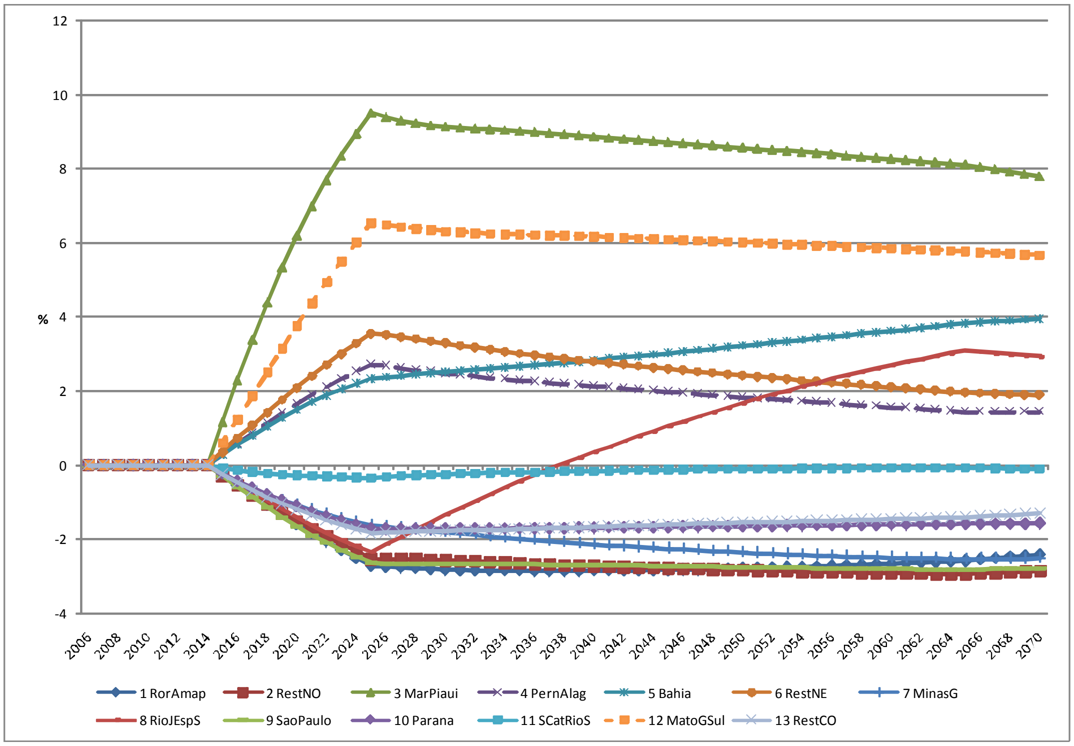

Figure 8: Model results. Inter-regional migration variation, by origin of migrants (%).

Model results presented in Figure 8 show an interesting picture of the possible effects of the simulated climate change scenarios. The first thing to be noticed is that the MarPiaui (Maranhão and Piaui states in Norheast) and MatoGSul (Mato Grosso do Sul state, in Center-west) regions are those which show the strongest increase in migration outflows, compared to the baseline. The accumulated final result for MarPiaui is an 8% increase in population outflows, and for MatGSul a 5.7% increase, compared to the baseline. However, the bulk of this effect happens during the first period scenario (2020/A2), when adaptation is not considered[8]. In 2025 the accumulated population outflow would increase by 9.5% for MarPiaui and 6.5% for MatGSul. The same pattern of migration evolution applies to the RestNE and PernAlagoas, regions inside the Northeast macroregion, although at smaller rates then MarPiaui. Again, the bulk of the effect in these regions also happens in the end of the first period scenario. After that the annual rate of population outflow falls, causing the migration path to dip, but never return to baseline values.

Bahia, the largest state in Northeast Brazil fares differently. Its outmigration flow increases continually, reaching its maximum at 2070, with an accumulated rate of 3.96% above the baseline. Despite this, the final observed result for this state is smaller than that of MarPiaui, around 4%.

The other regions inside the Southeast, South and Center-west (except MatoGSul, as seen before) would generally reduce their outmigration rates compared to the trend. The noticeable exception here is the RioJEspS sub-region, which combines the states of Rio de Janeiro and Espirito Santo in the Southeast macro region. Figure 8 shows that this region would reduce its outmigration rate in the first period. From 2026 on the yearly rate of outmigration would start to increase, causing the accumulated outmigration to become positive by 2038.

[8] Note that the paper does not deal directly with adaptation measures, which is included in the scenarios generated by EMBRAPA.

Another possible way to analyze the results is to look at migration by destination as shown in Figure 9[9]. Note that the RorAmapa (Roraima and Amapa states, in North macro region) is the region whither migration increases the most (in percentage variation terms), and there are increases too for the other states inside the North region (RestNO sub-region). This has important economic and social implications, since the occupation of the Amazon region is presently an issue of great concern for public policy.

The increase in the rate of migration to the northern regions, caused by climate change, would reproduce the trend observed in the seventies, when the Brazilian (military) government deliberately stimulated population migration from the Northeast to the North, under the "landless people for a land without people" initiative, a policy aimed at the occupation of the vast Amazon territory, which included the construction of the Transamazônica road. The intensification of population flows toward the North, of course, will depend on other possible effects of climate change on the region, not included in this paper, like the intensification of tropical diseases and so on. The results presented here, however, point to an increase in the pressure over the region's natural resources, arising from an increase in population.

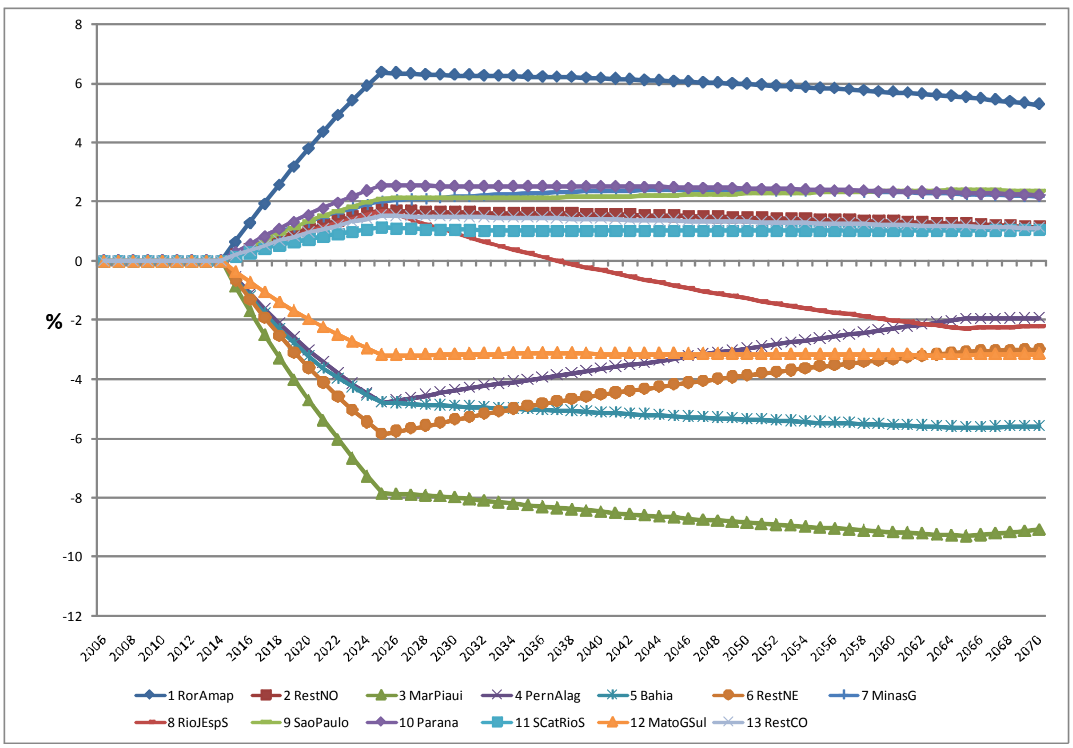

Figure 9: Regional migration in Brazil, by destination (%).

Model results show that the states in the Southeast and South macro regions would generally start to gain (relative to base) population due to the climate change scenarios. The rate of increase is not too big, reaching 2.7% for São Paulo, 2.2 for Parana and around 1% for StaCatRioS (Santa Catarina and Rio Grande do Sul). This is, however, an inversion of the migration trend observed since the beginning of the last decade, as discussed before. Again RioJEspS is an exception. This region would gain population until 2025 (the end of the first scenario period), and would start to lose population from then, with a negative final result around 2.19% less immigrants arriving to the sub-region compared to the baseline in 2070.

[9] Notice that the numbers here are not just the opposite as those seen before in Figure 8, since migration by

It should be noticed, however, that the absolute numbers of migrants involved are not very large. Figure 10 shows model results for the estimates of migration.

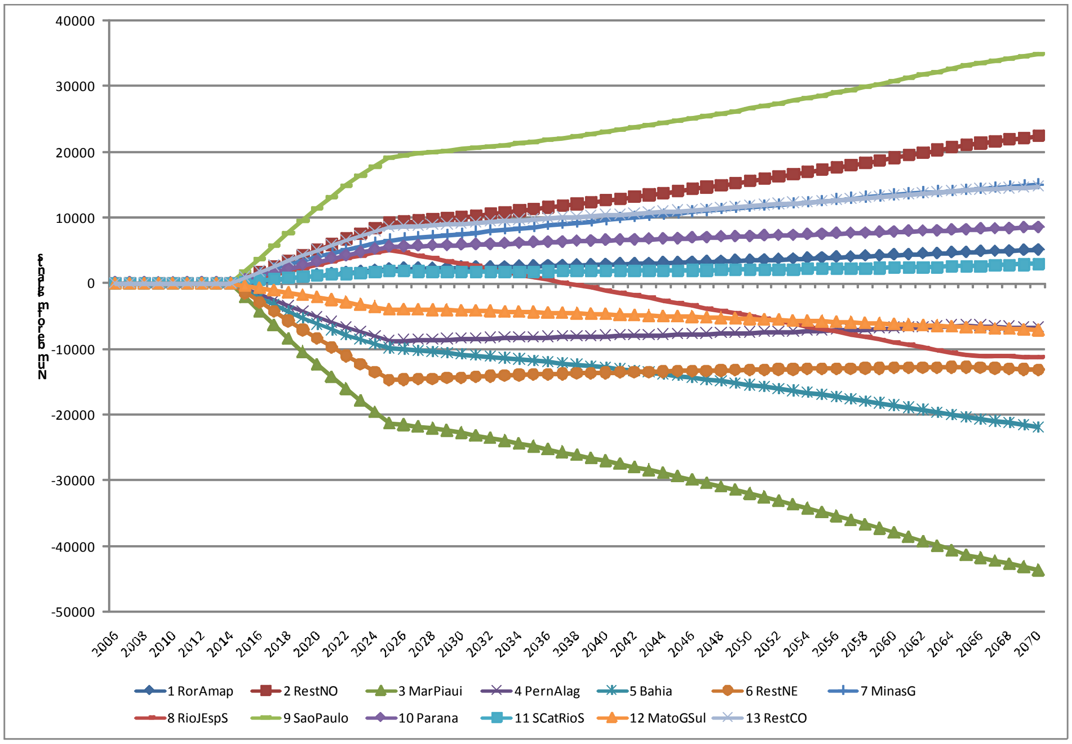

Figure 10: Net number of migrants, by destination.

It can be seen from Figure 10 that São Paulo, for example, the state that would receive the larger absolute number of migrants, would receive in the final period (2070) 34,958 more people than it would receive in the baseline, while MarPiaui, the sub-region that would lose more population, would lose 43,644 more people than in the baseline.

Another important point to be noticed here is the labor type composition of migration flows. The most negatively affected regions in the simulated scenarios are regions in Northeast Brazil, as well as in the Center-west. The structure of labor demand and different composition of agriculture in those regions will generate particular migration flows, when analyzed according to the type of labor group classification. Since is difficult to show time, skill and regional dimensions in a single diagram, we have chosen to present the accumulated result in the last year of the period. This can be seen in Figure 11. It shows that the regions receiving most of the migration flows (RorAmapa, MinasG, Sao Paulo, Parana, StaCatRioS and RestCO) all receive a higher share of the relatively unskilled workers, or those classified in occupation 1 to 3 (OCC1 to OCC3). This means that most of the migration flows would occur among the less qualified workers, which again echoes the migration patterns observed in the past[10]. The rapid increase in the migration of unskilled workers towards the big cities in Southeast Brazil caused the surge in the "favelas" (slums), still a very serious problem in the main cities. Again, the results here presented point to a movement in internal migration similar to what was observed in the past.

Figure 11 shows too that MatoGSul state which would be losing population in aggregate terms, would actually be receiving a positive inflow of less skilled workers (OCC1 and OCC2). This

destination computes the totals from different origins.

[10] Note that our migration function does not differentiate between different skills. Whether unskilled workers have more or less difficulty to migrate than skilled workers is an empirical issue, which will have to be considered for future work.

result is strongly related to the projected increase in cassava production in the state. Inspection of labor demand composition for this crop in the database reveals that about 60% of total labor payments in cassava go to workers in the first two occupational groups. The other states where cassava tends to increase production (Sao Paulo, RioJEspS and RestCO) have a much smaller share of unskilled workers in cassava production.

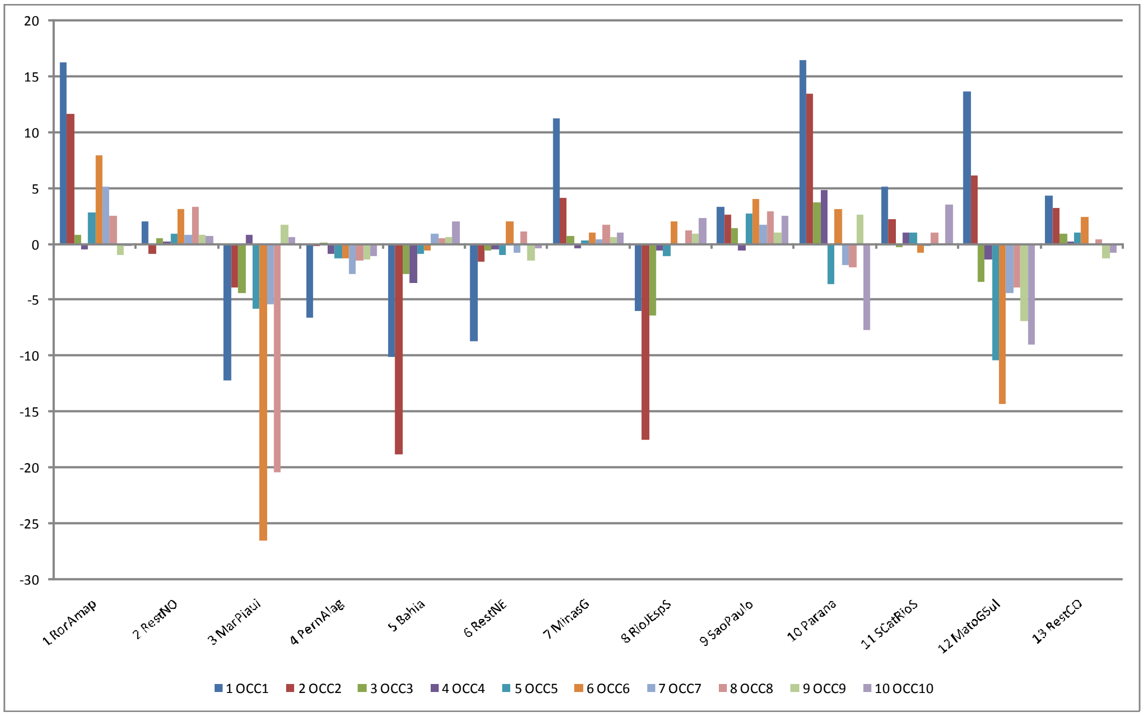

Figure 11. Migration by occupation and destination (accumulated, 2070, % change from baseline).

We should now point out that the migration concept used in this study involves only the personal (worker) dimension. Migration, however, is a complex phenomenon, and frequently involves the whole family, which may sooner or later follow the migrant worker. Indeed, Oliveira and Jannuzzi (2004) analyzed the reasons of migration in Brazil. According to those authors, based on a special supplementary survey in the PNAD 2001, the "search for jobs" is the most common reason for migration, especially among men: 34% of men and 11.8% of women have selected that as the main reason for migration. Altogether 23% of the surveyed persons declared that their main reason for migration was the search for jobs[11]. The answer "accompanying the family", on the other hand, accounted for 51.5% of the answers for the main reasons for migration (63% among women), and many different factors for the rest. This is, of course, due to the presence in the sample of children and teenagers below 14 years.

Our study's migration database included only persons above 15 years old. According to the same above mentioned authors, the youngest (around 20 years old) would be more prone to migrate than any other age group, and this would be strongly correlated to movements in the labor market. In this way, the high concentration of young person among migrants would be explained by their "sensibility" to bids in the job market, as well as for their higher adaptability to new situations (Oliveira and Jannuzzi, 2004).

Thus it is not absurd to consider that each migrant would bring two other relatives in his wake, at least in the medium run, which might triple the numbers observed in Figure 12. This is a point that deserves further elaboration in future studies.

8 Final remarks

The climate change scenarios simulated in this paper point to a reversal of the current pattern of internal migration in Brazil. The severe climate-induced effects on some Northeast states would cause a new pressure for migrants to leave those regions. Model results presented here point to the MarPiaui sub-region (Maranhao and Piaui states) as the most adversely effected in terms of agricultural production, increasing emigration from that region. Perhaps more surprisingly, the same would happen to Mato Grosso do Sul state, in the Center-west region. The Southeast and South regions would be the recipient regions, a movement that reverses current flows.

Perhaps even more worrying is the conclusion that the less skilled workers would be the larger part of migrants. This suggests that a new surge in the population movement impetus towards the already large slums in the Southeast cities could start to appear again in the near future. These low-wage workers, which belong to the most socially vulnerable groups, would be left with no option but migration, if adaptation measures are not put into action.

Another interesting point to be observed from the results presented here is the increase in migration towards the North regions. Even though, as observed before, the forecasted numbers are not very big, they may raise policy concerns. Increased migration towards the Amazon would increase the pressure over natural resources in that region — already a matter of great concern for the Brazilian government.

And, finally, a limitation of this study is that the results should be regarded as floor estimates, since they only refer to workers, and not families. The decision to migrate is a complex one; very often the family comes to join the main migrant later. We hope to analyze this aspect of the problem in future work.

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[11] In the 20 to 54 years old persons the "search for work" answer varies between 33.1% to 40.1% of answers.

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