ECONOMIC IMPACTS OF TRANSGENIC CORN ADOPTION IN BRAZIL[1]

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17th International Consortium on Applied Bioeconomy Research - ICABR Conference

Ravello, Italy. 2013

1 Introduction

Corn production in Brazil has been increasing continuously since 1990, reaching in 2011 a production of 55.7 million tons, against 21 million tons observed in 1990. The area under corn, however, remained fairly stable in the period, pointing to the fact that the abovementioned increases in productions happened mainly due to strong gains in productivity, as it can be seen in Figure 1.

[1] The authors thank the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES for funding the paper presentation at the Conference.

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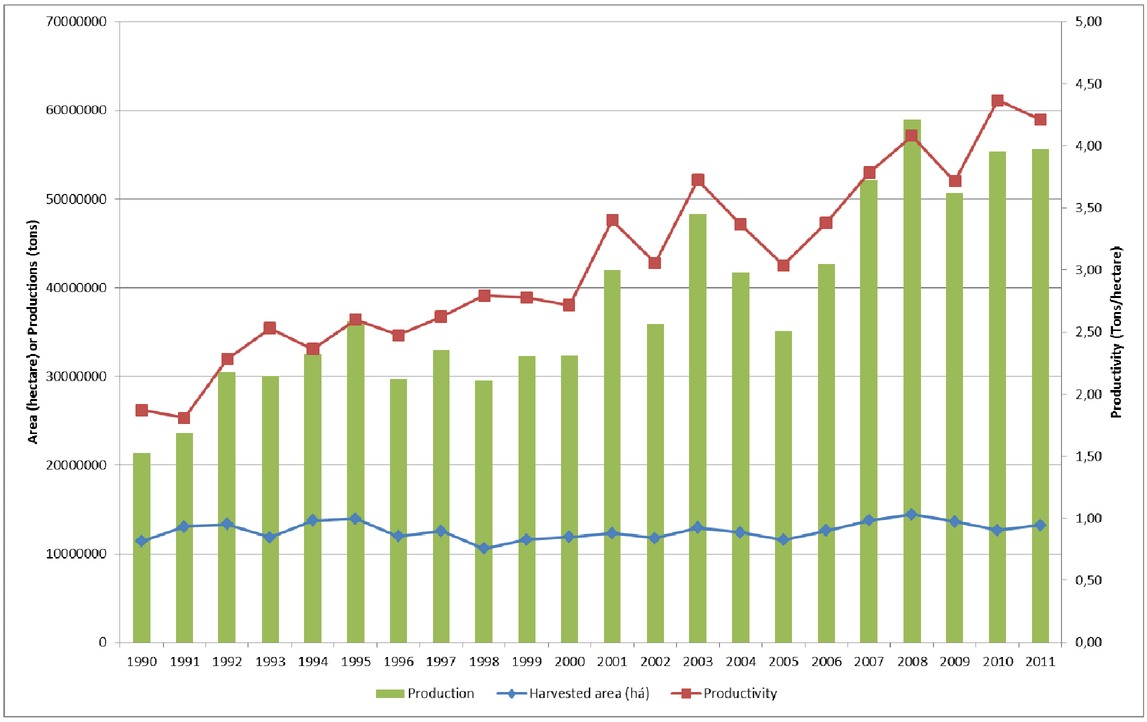

Figure 1. Corn production, area and productivity. Brazil, 1990-2011.

The production of corn in Brazil is spread along the country´s territory, in two crops in each season. The first corn crop starts in September and October – spring – and the second corn crop is planted mostly after soybeans in January and February (summer), depending on the region under consideration.

Considering the total, the most important state in production is Parana, in the South region, while the second most important state is Mato Grosso, in the Center-west region. Minas Gerais, Rio Grande do Sul and Goias are also important producing states. In aggregate, the South-Southeast regions of Brazil still produce about 57% of total corn in the country, despite the recent increase in the Center-west share. The regional distribution of corn production in Brazil can be seen in Figure 2.

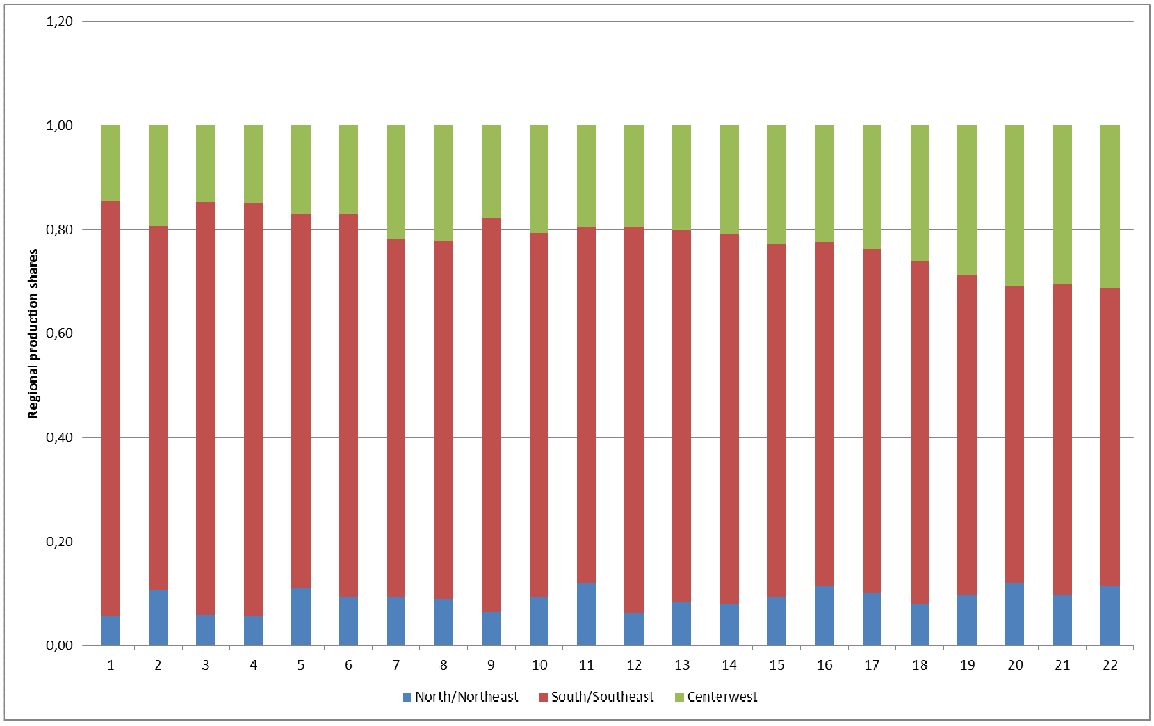

Figure 2. Corn regional production shares. Brazil. 1990-2011.

The first transgenic event for corn in Brazil was authorized in 2007, with the MON810 insect resistant variety. Presently fourteen events are authorized for corn in Brazil, seven of which insect resistant (IR), two with herbicide tolerance (HT) and five with stacked IR and HT.

The use of GM corn became widespread in Brazil. According to the field survey which supports this study, conducted by CEPEA in the 2010/2011 crop (to be described in further details below), the use of GM corn was at least as common as the non GM, both in the first and the second crops in Brazil. In many places the use of conventional corn was reported only in refugees' areas (about 10% of the area under production in each farm). The insect resistant GM corn was the most common GM technology in use. According to that survey, both the HT and the stacked varieties are still in experimental use. The CEPEA survey also covered other aspects related to the use of GM corn. In particular, no seed shortage was reported for the 2010/2011 year, and the comparative productivity between GM and non GM varieties was the same in most of the surveyed regions.

The use of GM seeds entails a significant change in production technology, and as such is likely to have impacts on the system as a whole. These effects are complex, and spill over the agriculture sphere, spreading to the commercialization system and the economy. In order to have a more thorough examination of those effects, in this paper a quantitative assessment of the impacts of GM corn use in Brazil is done, through the use of a general equilibrium model of the Brazilian economy.

2 Methodology

The methodology used is this study has two main compounds, a field survey on costs of production, and the use of a computable general equilibrium model of Brazil. I what follows we briefly describe those two parts of the research.

2.1 The field survey on cost impacts of GM corn in Brazil

A field survey was conduct by CEPEA[4] in the main corn producing regions in Brazil, in the 2010/2011 crop, with the purpose of getting information about cost structures of different corn production systems, as well as other producing characteristics. The survey was performed through meetings with producers and technicians linked to corn production, where cost spreadsheets were organized for the typical producing units in each region. Table 1 displays the regions and type of production systems analyzed.

According to the information reported in the CEPEA survey, the rate of adoption of GM corn in Brazil in 2010/2011 was estimated to be around 55% of total corn area in Brazil. This estimate is close to the one by Celeres (2012), which estimate a rate of adoption of GM corn in 2010/2011 around 58%. The survey design, then, tried to capture the diversity of situations which exist in a large country like Brazil, with different natural conditions across the territory.

Table 1. Surveyed regions . Corn production costs, GM x NGM. Brazil. 2010/2011.

Region	State	Crop	GM use reported
Rio Verde (RVD)	Goias	First crop	Yes (IR)
		Second crop	Yes (IR)
Mineiros (MNR)	Goias	First crop	Yes (IR)
		Second crop	Yes (IR)
Uberaba (UBR)	Minas Gerais	First crop	Yes (IR)
Unaí (UNAI)	Minas Gerais	First crop	Yes (IR)
		Second crop	Yes (IR)
Xanxerê (XNX)	Santa Catarina	First crop	Yes (IR)
Campos Novos (CNV)	Santa Catarina	First crop	Yes (IR)
Castro (CST)	Paraná	First crop	Yes (IR)
Guarapuava (GPVA)	Paraná	First crop	Yes (IR)
Cascavel (CVEL)	Paraná	First crop	Yes (IR)
		Second crop	Yes (IR)
Londrina (LDN)	Paraná	First crop	Yes (IR)
		Second crop	Yes (IR)

[4] CEPEA is the Center for Advanced Studies on Applied Economics, a research center based at the Department of Economics, Management and Sociology of the Escola Superior de Agricultura "Luiz de Queiroz", University of Sao Paulo, at Piracicaba, SP, Brazil. (http://www.cepea.esalq.usp.br/).

Source: CEPEA field survey.

In total, 28 different cost structures of corn were surveyed, being eight conventional in first crop, ten GM corn in first crop, five conventional corn in second crop, and five GM corn in second crop. As mentioned before, most of the GM corn presently in use in Brazil is IR corn, as can be seen in Table 1.

The cost results for the different production systems can be seen in Table 2 and Table 3. In the tables, Operational Costs refer basically to inputs (variable) costs; the Total Operational Costs include fixed costs and depreciation of capital stocks, and Total Costs include the opportunity costs of land and the capital stock. As it can be seen from the tables, the cost differential between GM and non GM crops inside each region and season is not very big. However, the costs can vary considerably across regions, reflecting different levels of technology and productivity.

Table 2. Cost comparison between GM x non GM corn, first crop. Brazil, 2010/2011.

Item	LDN		CVEL		GPVA		CST		XNX		CNV		RVD		UBR	
	GM	Non GM	GM	Non GM	GM	Non GM	GM	Non GM	GM	Non GM	GM	Non GM	GM	Non GM	GM	Non GM
Fertilizers	486,98	486,98	518,74	518,74	647,06	647,06	752,52	752,52	969,52	969,52	616,15	616,15	607,08	607,08	652,92	652,92
Chemical inputs	157,64	232,40	158,65	200,57	213,78	217,80	174,36	252,98	179,69	213,59	178,15	208,75	187,20	280,40	186,40	248,40
Herbicides	76,24	76,24	86,50	86,50	108,00	108,00	70,80	70,80	98,75	98,75	109,75	109,75	68,50	68,50	101,50	101,50
Insecticides	12,40	87,15	8,93	50,85	3,90	7,92	20,43	99,05	31,80	65,70	25,50	40,50	2,70	95,90	0,00	62,00
Fungicides	31,82	31,82	0,00	0,00	50,00	50,00	32,45	32,45	0,00	0,00	0,00	0,00	62,00	62,00	55,20	55,20
Seed treatment	37,19	37,19	63,22	63,22	51,88	51,88	50,68	50,68	49,14	49,14	42,90	58,50	54,00	54,00	29,70	29,70
Seeds	392,56	309,92	433,88	309,92	437,50	312,50	390,00	299,00	444,60	396,50	437,50	337,50	330,00	220,00	450,00	288,00
Emulsionable oil	3,76	3,76	0,00	0,00	2,80	2,80	2,00	2,00	0,00	0,00	0,00	0,00	5,60	5,60	0,00	0,00
Mechanical operations	224,35	228,69	224,54	242,18	236,92	236,92	204,49	213,81	201,43	201,43	207,44	214,07	166,44	167,49	173,43	173,43
Transportation	144,63	144,63	191,47	191,47	157,50	157,50	157,35	157,35	136,00	136,00	96,00	96,00	150,00	150,00	160,00	160,00
Labor	116,28	118,16	62,31	65,40	130,66	130,66	47,52	50,76	65,07	65,07	45,53	47,38	105,41	108,09	45,39	45,39
Trade/Storage	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	39,36	39,36	0,00	0,00	0,00	0,00	0,00	0,00
Taxes	68,19	68,19	86,88	86,88	99,42	99,42	83,49	83,49	90,52	85,19	92,37	83,13	65,90	65,90	82,43	72,13
Insurance	6,59	6,82	16,20	16,78	16,28	16,28	14,99	15,34	17,37	17,37	15,53	15,74	10,36	10,42	11,40	11,40
Technical assistance	30,52	30,49	31,79	30,57	36,52	34,10	34,56	34,57	39,93	39,64	31,62	30,40	31,03	30,77	33,36	31,36
Interest over capital	131,81	131,69	113,84	109,92	136,49	128,15	156,75	156,76	149,09	148,12	103,88	100,10	134,50	133,47	109,55	103,55
Operational costs	1763,33	1761,72	1838,30	1772,43	2114,92	1983,19	2018,04	2018,59	2332,58	2311,79	1824,17	1749,23	1793,52	1779,21	1904,87	1786,57
Total Operational Costs	1835,30	1832,05	2025,32	1970,33	2320,66	2188,92	2209,62	2216,71	2535,51	2514,73	2015,32	1944,22	1943,44	1929,79	2051,19	1932,89
Total Costs	2306,07	2306,21	2644,45	2598,23	2839,97	2708,23	2779,07	2791,44	3124,37	3103,59	2562,07	2493,50	2364,61	2351,49	2560,14	2441,84

Source: CEPEA survey.

Table 3. Cost comparison between GM x non GM corn, second crop. Brazil, 2010/2011.

Item	RVD		MNR		CVEL		LDN		UNAI	
	GM	Non GM	GM	Non GM	GM	Non GM	GM	Non GM	GM	Non GM
Fertilizers	**516,41**	**516,41**	**324,53**	**324,53**	**260,91**	**260,91**	**209,30**	**209,30**	**318,70**	**318,70**
Chemical inputs	**128,50**	**158,40**	**147,10**	**197,10**	**192,42**	**217,85**	**129,95**	**204,70**	**132,95**	**183,05**
Herbicides	43,50	43,50	46,50	46,50	60,45	60,45	47,31	47,31	98,35	98,35
Insecticides	0,00	29,90	19,60	69,60	32,93	58,35	12,40	87,15	1,60	51,70
Fungicides	31,00	31,00	27,00	27,00	42,15	42,15	31,82	31,82	33,00	33,00
Seed treatment	54,00	54,00	54,00	54,00	56,90	56,90	38,42	38,42	0,00	0,00
Seeds	**280,50**	**160,00**	**252,00**	**162,00**	**368,18**	**256,61**	**392,56**	**289,26**	**264,00**	**220,00**
Emulsionable oil	**0,00**	**0,00**	**12,00**	**12,00**	**4,65**	**4,65**	**3,76**	**3,76**	**4,00**	**4,00**
Mechanical operations	**157,11**	**158,08**	**159,73**	**163,54**	**193,71**	**225,26**	**173,21**	**179,54**	**190,04**	**207,19**
Transportation	**80,00**	**80,00**	**63,00**	**63,00**	**96,00**	**96,00**	**56,20**	**56,20**	**80,00**	**80,00**
Labor	**99,27**	**101,95**	**65,09**	**65,57**	**48,97**	**50,51**	**84,40**	**94,23**	**113,68**	**116,70**
Trade/Storage	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
Taxes	**36,98**	**36,98**	**31,64**	**31,64**	**44,16**	**44,16**	**35,22**	**35,22**	**40,48**	**40,48**
Insurance	**9,61**	**9,61**	**12,05**	**12,20**	**12,85**	**12,85**	**6,05**	**6,50**	**13,06**	**13,88**
Technical assistance	**25,24**	**23,50**	**20,47**	**19,75**	**23,30**	**22,24**	**20,99**	**20,74**	**22,07**	**22,59**
Interest over capital	**161,65**	**150,51**	**125,09**	**120,73**	**121,91**	**116,36**	**124,36**	**122,89**	**115,42**	**118,16**
Operational costs	**1495,27**	**1395,44**	**1212,70**	**1172,04**	**1367,06**	**1307,40**	**1235,99**	**1222,35**	**1294,40**	**1324,76**
Total Operational Cost	**1633,02**	**1532,38**	**1388,17**	**1349,22**	**1510,67**	**1451,01**	**1292,75**	**1287,52**	**1442,56**	**1486,47**
Total Costs	**1891,55**	**1790,27**	**1655,70**	**1618,13**	**1832,36**	**1772,70**	**1611,01**	**1612,55**	**1599,04**	**1653,89**

Source: CEPEA survey.

Once the different cost structures for GM and non-GM corn is known, the next step was to calculate the cost differential for the two technologies, what can be seen in Table 4 and Table 5. The figures in those tables mean the percentage change variation entailed by the use of GM seeds in each situation, in relation to the cost of the non-GM seeds. It can be seen, then, as the cost impact caused by the GM technology in each region and situation.

Table 4. Cost comparison between GM x non GM corn. First crop, Brazil, 2010/2011. Percent variation in relation to the non-GM technology.

	VARIATION [(GM-Non GM)/non GM]							
Item	LDN	CVEL	GPVA	CST	XNX	CNV	RVD	UBR
	% variation	% variation	% variation	% variation	% variation	% variation	% variation	% variation
Fertilizers	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Chemical inputs	-32,17	-20,90	-1,85	-31,08	-15,87	-14,66	-33,24	-24,96
Herbicides	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Insecticides	-85,78	-82,45	-50,76	-79,38	-51,60	-37,04	-97,18	-100,00
Fungicides	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Seed treatment	0,00	0,00	0,00	0,00	0,00	-26,67	0,00	0,00
Seeds	26,67	40,00	40,00	30,43	12,13	29,63	50,00	56,25
Emulsionable oil	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Mechanical operations	-1,89	-7,29	0,00	-4,36	0,00	-3,10	-0,63	0,00
Transportation	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Labor	-1,59	-4,73	0,00	-6,39	0,00	-3,91	-2,48	0,00
Trade/Storage	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Taxes	0,00	0,00	0,00	0,00	6,25	11,11	0,00	14,29
Insurance	-3,35	-3,47	0,00	-2,26	0,00	-1,31	-0,54	0,00
Technical assistance	0,11	4,01	7,09	-0,01	0,72	4,01	0,85	6,38
Interest over capital	0,09	3,57	6,51	-0,01	0,66	3,77	0,77	5,80
CO	0,09	3,72	6,64	-0,03	0,90	4,28	0,80	6,62
COT	0,18	2,79	6,02	-0,32	0,83	3,66	0,71	6,12
CT	-0,01	1,78	4,86	-0,44	0,67	2,75	0,56	4,84

Table 5. Cost comparison between corn GM x non GM. Second crop. Brazil, 2010/2011. Percent variation in relation to the non-GM technology.

	Variation [(GM-Non GM)/non GM]				
Item	RVD	MNR	CVEL	LDN	UNAI
	% variation	% variation	% variation	% variation	% variation
Fertilizers	0,00	0,00	0,00	0,00	0,00
Chemical inputs	-18,88	-25,37	-11,67	-36,52	-27,37
Herbicides	0,00	0,00	0,00	0,00	0,00

Insecticides	-100,00	-71,84	-43,57	-85,78	-96,91
Fungicides	0,00	0,00	0,00	0,00	0,00
Seed treatment	0,00	0,00	0,00	0,00	0.00
Seeds	75,31	55,56	43,48	35,71	20,00
Emulsionable oil	0	0,00	0,00	0,00	0,00
Mechanical operations	-0,62	-2,33	-14,01	-3,53	-8,28
Transportation	0,00	0,00	0,00	0,00	0,00
Labor	-2,62	-0,73	-3,06	-10,44	-2,59
Trade/Storage	0,00	0,00	0,00	0,00	0,00
Taxes	0,00	0,00	0,00	0,00	0,00
Insurance	0,10	-1,18	0,00	-7,03	-5,91
Technical assistance	7,40	3,62	4,77	1,19	-2,33
Interest over capital	7,40	3,62	4,77	1,19	-2,33
CO	7,15	3,47	4,56	1,12	-2,29
COT	6,57	2,89	4,11	0,41	-2,95
CT	5,66	2,32	3,37	-0,10	-3,32

Source: CEPEA survey.

As can be seen from the data in the tables above, there is a substantial reduction in chemical inputs use due to the GM technology in most regions. We see from Table 4, for example, that the use of chemical inputs in Londrina (LDN) is 32.17% lower in the GM corn compared to the conventional culture, and that this reduction is mainly due to the fall in insecticide use. The cost of seeds, on the other hand, was 26.67% higher for the GM corn in that region. Actually, it can be observed that the operational costs (CO) increases for most regions, since the strong increase in the cost with seeds is not compensated by the fall in other costs items, mainly chemical inputs.

The observed values for the shocks may be particular to the year surveyed by CEPEA, and to particular circumstances in that year of region. In particular, the regional distribution of cost shares may vary between years, and only a detailed time series of spreadsheets costs would allow a better idea of the "typical" cost reduction due to the GM corn seeds use. This information, however, is not available. In order to get insight about possible variations, then, the simulation will be performed with stylized shocks, calculated departing from the field data above. In order to generate the shocks to the model, the information above has to be summarized to get the general insights of the technology impacts.

This is done first averaging the percentage change observed in each region, in each crop. In the first crop, for example, there are three regions inside Parana state, and the results observed for those regions were averaged to get the average percentage change in cost in Parana. The same was done for all the other regions. The second step was to calculate the weighted average of the reduction in the two crops, for each state. Then the weighted average change in cost for Brazil was calculated, using as weights the share of each state corn production in the total corn production of the surveyed states. And the final step was to multiply those variations by the adoption rate in

2010/1011 estimated by Celeres (2011), which was around 58% or GM corn in that year[5]. This strategy results in an average operational cost increase of 1.97% for Brazil. The cost shock to each cost item can be seen in Table 6.

The shocks to the model will be implemented applying the inputs cost variations observed in the field survey. The definition of sectors in the CGE model, however, is not as disaggregated as the one presented in the cost spreadsheets above. The shocks, then, have to be attributed to the sectors in the model, what is done through a mapping that can also be seen Table 6.

Table 6. Regional costs of production index variation. Percentage change.

Description in cost spreadsheet	Description in CGE model	Shocks (%)
Chemical inputs	Inorganic Chemicals	-13.6
Seeds	Seeds	29.5
Mechanical operations	Machines and vehicles	-1.75
Insurance + Technical assistance	Services	1.0
Labor	Labor	-1.65

In the CGE database classification, corn seeds are considered an agricultural product. The increase in the price of GM seeds, then, was simulated through an increase of a tax on seeds, to avoid this extra income being directed to agriculture. This gives the desired increase in costs, without biasing agricultural incomes. Considering government spending is fixed in the simulation, this causes no other problems, since all what happens is to allow a slight change in government budget surplus (or, conversely, a reduction in deficit). And, finally, CGE models don´t deal with monetary instruments, and so the small changes in interest spending observed in the cost spreadsheets were just disregarded.

The implementation of those cost shocks to the model gives an increase in operational costs of 1.86%, close to what was observed in the CEPEA survey (in the aggregated, weighted average results), mentioned before. This increase in costs was observed in most surveyed regions, and is an interesting result since, despite this cost increase, the use of GM corn is spreading fast in Brazil, as shown before. Productivity increases in GM corn were reported in the first crop corn in some regions, namely in UBR (14.2%), XNX (6.2%) and CNV (11.1%) when compared with the conventional corn, but not in the other regions or in the second crop.

Based on our data, then, the rapid adoption of GM technology in Brazil is not related to increases in productivity caused by the technology. But the fast increase in the use of GM corn varieties in the country suggests that other variables related to production may be also improving,

[5] Celeres estimates of rates of adoption of GM technology for 2012/2013 in corn are around 64.8% (5.3 million hectares) for the first crop and 87.8% (6.9 million hectares) for the second crop (Celeres, 2012).

as is the case of risk reduction in production. Indeed, this point was directly raised during the surveys, and production risk reduction was pointed out as the reason to adopt GM corn.

This suggests that producers are willing to accept a lower rate of return to the investments in corn production in the long run in exchange for the reduction in production risk borne by GM seeds. GM technology thus is regarded as a kind of insurance against insect infestations. This is a relevant effect, and in this paper we will use the CGE model to get insight about the size of this effect. For this purpose a counterfactual simulation will be conducted, where corn production will be fixed at the base year level. Once the cost increasing shocks are applied, the model will calculate the fall in the Gross rate of Return to capital (GRET) necessary to ratify the cost increase, without any production loss. The simulation for the impacts of GM corn adoption, then, will comprise two main aspects:

- The shocks calculated in Table 6 are applied to all regions, and
- The simulation will calculate the required fall in GRET[6] to keep corn production constant in the presence of the cost increase due to GM technology. The fall in GRET, then, can be regarded as a measure of the size of production risk perception due to pest (worms) infestation in corn production.

2.2 The Computable General Equilibrium model

In this study we used a computable general equilibrium (CGE) model of Brazil to assess the economic impacts of the introduction of this new technology in corn producing in Brazil. General equilibrium models are economy wide models that allow an integrated view of the economy, through a detailed description of the products and factor markets, as well as of their linkages. They differ from partial equilibrium markets by explicitly modeling the circular flows of funds in an economy, recognizing the interactions between the many different markets in a domestic economy, the factor markets and the international markets.

The CGE model used here, TERM-BR, is a static inter-regional model of Brazil based on the TERM model of Australia (Horridge, Madden and Wittwer, 2005), and been used extensively in Brazil in other studies, like Ferreira Filho and Horridge (2009, 2010, 2011a, 2011b); Fachinello (2010); Pavão (2011); and Moraes (2011).

It consists, in essence, of 27 separate CGE models (one for each Brazilian state), linked by the markets for goods and factors. For each region, each industry and final demander combines Brazilian and imported versions of each commodity to produce a user-specific constant elasticity of substitution (CES) composite good. Household consumption of these domestic/imported composites is modeled through the Linear Expenditure System, while intermediate demand has a Leontief (fixed proportions) structure. Industry demands for primary factors follow a CES pattern, while labor is itself a CES function of 10 different labor types. These different labor types are

[6] The GRET is defined in the model as the percentage change in the ratio rental/price of new capital.

classified according to wages, as a proxy for skills. The model distinguishes 42 producing sectors (or industries), each of which producing one commodity. Agricultural land is also distributed among the agricultural activities through a CET frontier. Export volumes are determined by constant-elasticity foreign demand schedules.

These regional CGE models are linked by trade in goods underpinned by large arrays of inter-regional trade that record, for each commodity, source region and destination region, the values of Brazilian and foreign goods transported, as well as the associated transport or trade margins. São Paulo users of, say, vegetables substitute between vegetables produced in the 27 states according to their relative prices, under a CES demand system.

With 27 regions, 42 industries, 42 commodities, and 10 labor types, the model contains around 650 thousand non-linear equations, and is solved with GEMPACK (Harrison and Pearson, 1996). The CGE model is calibrated with data from the 2005 Brazilian Input-Output Matrix, some shares derived from the Pesquisa Agrícola Municipal (IBGE, 2005, available at http://ibge.gov.br), and from the Pesquisa de Orçamentos Familiares (Expenditure Survey, POF).

On the income generation side of the model, workers are divided into 10 different categories (occupations), according to their wages. Together with the revenues from other endowments (capital and land rents) these wages contribute to regional household incomes. Each industry in each region uses a particular mix of the 10 different labor occupations (skills). Changes in activity level change employment by sector and region. Using the expenditure survey (POF, mentioned below) data the CGE model was extended to cover 270 different expenditure patterns, composed of 10 different household income classes in 27 regions.

3 Simulation and model closure

As stated before, the model is calibrated with data for year 2005, a year when there was no GM corn approved for field use in Brazil. The simulation to be performed, then, comprises the introduction of shocks to the production system caused by this new technology, as discussed before. The variation in use of inputs and labor will then be transmitted to the model, and a new equilibrium will be calculated, which shows the general economic adjustment required to accommodate the new technology.

An important aspect of any CGE model is its closure rules, which determines the way the model reaches a new equilibrium after a shock. In this simulation a long run closure is used, given the nature of the expected gains in GM corn adoption, with the following characteristics:

- Capital stock is endogenous by industry, while the Gross Rate of Return (GRET) in each production sector is exogenous. This means that by assumption capital stocks adjust to ratify the fixed GRET by industry. The exception to this rule is the corn production activity, where the GRET will be endogenously adjusted in order to keep corn production fixed at the base year value, as discussed earlier.

- Land stocks are fixed in each region, but mobile between agricultural activities inside regions, through a CET mechanism driven by profitability.
- Real wages are endogenous, and aggregate employment is fixed. Labor can migrate between regions and activities, driven by real wages changes. Initial inter-regional labor differentials are not eliminated.
- Total (aggregated) investment in the economy is endogenous, and follows aggregated capital stock.
- The GDP price index is the model´s numéraire.

With this closure conditioning the macro adjustment of the model, the shocks discussed previously are transmitted to the model, and a new equilibrium is calculated. The results will be discussed in the next section.

4 Results

The total value of corn production in Brazil in the base year (2005) represented about 0.29% of total value of production in Brazil, and about 6% of total value of primary agriculture and livestock. The shocks, then, will produce only small changes at aggregate level in the Brazilian economy.

The introduction of GM corn under the scenario described above generates a GDP change around 0.015% in the simulation, compared to the database, where there was no GM corn, as it can be seen in Table 7. This is accompanied by a slight depreciation of the currency (as measured by the difference between the imports price index and the GDP deflator percentage changes). These small changes, of course, are a consequence of the small share of corn in the national economy, in values.

Table 7. Model results, selected macro variables. Percent variation.

Macro variable	% variation
Real Household Consumption	0,012
Real Exports	0,005
Real Imports	0,002
Real GDP	0,015
GDP Price Index	Númeraire
Consumer Price Index (CPI)	-0,001
Exports Price Index	-0,001
Imports Price Index	0,001

Source: model results.

The GDP increase is directly related to the reduction in GRET. This means that the acceptance of a reduction in the GRET in the long run in corn production compensates for the cost increase generated by the GM technology. The results on land use and production for the agriculture and livestock activities in the model can be seen in Table 8.

Table 8. Land use and production variation for agricultural products. Percentage change.

	Land use	Production
Agricultural sector		
Rice	0,07	0,02
Corn	-1,26	0,00 (fixed)
Other	0,08	0,01
Sugar cane	0,07	0,01
Soybean	0,10	0,03
Cotton	0,06	0,02
Forestry	0,08	0,01
Livestock	0,09	0,03
Milk	0,11	0,02

Source: model results.

As it can be seen from the table, there is a fall in land use for the same production of corn in the long run, as well as an increase in production of the other agricultural products. This happens because the fall in the GRET is generated in the model by an increase in capital accumulation in corn production, required to drive the GRET down in the long run. This capital accumulation in corn productions allows limited substitution[7] of land by capital as a primary production factor, driving down the land use in corn production. Corn production with GM seeds, then, makes the activity more capital intensive in the simulation, releasing land for other uses and allowing the other agricultural activities to increase production, a positive effect of the production risk reduction in the activity[8].

Considering agricultural production is unevenly dispersed in the Brazilian territory, there will be different effects across the Brazilian states. The regional impacts of GM corn technology on GRET can be seen in Table 9.

Table 9. Regional GRET variation in corn production. Percentage change.

	GRET % variation
State	

[7] The value of the CES elasticity of substitution between primary factors (land, labor and capital) in the model is 0.5.

[8] It should be noticed that the relative fall in labor use was observed in the survey.

Bahia	-48,3
Minas Gerais	-46,6
São Paulo	-32,9
Parana	-30,0
Santa Catarina	-30,5
Rio Grande do Sul	-30,9
Mato Grosso do Sul	-38,2
Mato Grosso	-46,0
Goias	-46,6
Brazil	-38,2

Source: model results.

In Table 9, only results for the most relevant corn production states are displayed. As it can be seen, Parana (the most important corn producer in Brazil) is the state in which the lower fall in GRET would be observed. At national level, a 38.2% fall in GRET is generated in the model. This fall in GRET in corn production, then, can be considered, in the simulation conditions, as the value, expressed in terms of the (percentage change) in the rate of return to capital in the activity for producers, of the fall in production risk borne by GM technology. A fill points should be mentioned in regard to the interpretation of this result.

First, it should be noticed that this fall in GRET is conditional to what happens in each year. The calculated value is an “ex post” evaluation based on the observed conditions of the particular surveyed year, and does not necessarily reflect the “ex ante” expectations, or the “ex ante” willingness to pay for risk reduction of producers. The surveyed year was not a year of severe infestation of pests, what made production in GM and non-GM crops virtually the same, that is, no differential production was observed for the two different technologies. In a year of severe worm infestation the results could be very different, since in this case production in the GM technology would likely be greater.

Second, it should also be reminded that corn in Brazil is produced in two crops during the year, and the second crop accounts for about 35% of total production. The observed fall in GRET, then, is an aggregation of two crops. And finally, the results don´t take into account the side benefits generated by the two crops system, as is the case of soil covering and organic matter incorporation. These benefits - which are not incorporated in our accounting – can be important counterweights to the elevated calculated fall in GRET.

Labor demand was imposed to be reduced in the aggregate, according to the survey information. The particular labor composition of each activity, however, translates the aggregated change in different impacts across different labor types, as can be seen Table 10.

Table 10. Model results. Labor demand impacts, by labor type. Percentage change.

State	1 OCC1	2 OCC2	3 OCC3	4 OCC4	5 OCC5	6 OCC6	7 OCC7	8 OCC8	9 OCC9	10 OCC10

Bahia	-0,07	-0,02	0,00	-0,01	0,00	0,01	0,01	0,01	0,00	0,00
Minas Gerais	-0,27	-0,09	-0,01	-0,01	-0,01	0,01	0,00	0,01	0,01	0,01
São Paulo	-0,03	-0,02	-0,01	-0,01	-0,01	0,00	0,00	0,00	0,00	0,00
Parana	-0,33	-0,15	-0,02	-0,01	0,02	-0,01	0,00	-0,01	-0,01	0,00
Santa Catarina	-0,36	-0,06	-0,03	-0,03	0,02	0,00	0,01	0,01	0,01	0,00
Rio Grande do Sul	-0,14	-0,03	0,00	-0,01	0,00	0,00	0,00	0,01	0,00	0,00
Mato Grosso Sul	-0,14	-0,10	0,02	-0,10	-0,09	-0,01	0,02	0,02	0,01	0,01
Mato Grosso	-0,65	-0,24	-0,06	0,03	-0,01	0,01	0,01	-0,03	0,02	0,02
Goias	-0,09	-0,03	-0,03	0,00	-0,04	-0,04	-0,01	0,00	0,00	0,01

Table 10 shows the impacts on labor demand by state, according to the model´s 10 different types of labor, where OCC1 stands for the lowest wage group, and OCC10 of the highest. This classification is a proxy for skills. As it can be seen, labor demand falls more in the less skilled worker groups, notably in Parana, Santa Catarina and Mato Grosso. The change of technology to a more capital intensive pattern is the cause of this effect.

5 Final remarks

The introduction of GM corn in Brazil is not likely to generate important general equilibrium effects on the Brazilian economy, due to the small share of corn production value in the total Brazilian economy. The field survey showed that the GM corn technology is cost increasing, and the reduction in production risk is found to be the main reason to explain why the use of GM seeds is spreading fast in Brazilian agriculture. This implies producers are willing to accept, in the long run, a reduction in the rate of return in the activity. The simulation shows that a 38.2% fall in the rate of return in the activity would be required in order to keep corn production constant in the presence of the increase in costs, a value that can be regarded as a measure of risk perception in corn production in the simulation. It should be noticed, however, that this measure is particular to what was observed in the surveyed year, when worm infestation in corn production was low.

At the same time, labor demand for the less skilled workers in the economy would tend to be reduced. The introduction of the GM technology in corn production in Brazil, then, is associated to an intensification of capital use in the activity, with negative impacts on labor demand. This change, however, has positive spillovers to other agricultural activities, which tend to increase their level of production in the simulations.

The adoption of the GM technology in corn also generates increases in GDP, a result determined mostly by the saving of primary factors (notably land and labor) in the economy, which tend to be substituted by capital in the production process. These results point to a social gain, and reinforce the general (private) perception of benefits by producers, as expressed by the rapid increase in the rate of adoption of GM seeds.

Finally, it´s worth mentioning that the simulation was based in only one year of observation of the cost effects of the GM technology. More field surveys in different years would be necessary in order get to better information on costs and returns under different natural conditions for production. Increases in productivity, for example, were reported in some regions and crops in the CEPEA survey, but weren´t included in the simulations, what would considerably improve the benefits of the GM technology. At the same time, field observations in the 2012/2013 crop revealed problems with insect resistance in certain regions, with serious damages for the crops.

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