EVALUATING THE SOCIAL GAINS ASSOCIATED WITH TECHNOLOGICAL PROGRESS IN THE BRAZILIAN AGRICULTURE

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1 Introdução

The share of agriculture in the Brazilian exports started to rise again from 1994 on, after falling consistently since the middle of the seventies. The rate of growth of agricultural GDP has also been increasing at rates higher than the national GDP, particularly since the end of the nineties.

This dynamism of the Brazilian agriculture has as special feature the change in the pattern of geographical concentration, with new regions being incorporated to the process at fast rates. This change is accompanied by an intense process of technological change, with strong increase in the total factor productivity (TFP).

The agricultural sector is a key sector in the Brazilian economy in many different aspects. With strong forward and backward linkages, agricultural GDP accounted for 10.3% of total Brazilian GDP in 2003 (IBGE, 2004), and rural population still accounted for about 19% of total population in 2003. It's just natural, then, that those changes in the agricultural sector have important impacts in the economy as a whole. Due to its particular characteristics, both in the labor market and as a food supplier, these impacts are of complex nature, with net results depending in a great deal of the structural characteristics of the economy. The analysis of the broad effects of technological change in agriculture is the goals of this study.

2 Objective

The objective of this paper is to assess the effects of the technological progress in the Brazilian agriculture, both on the agricultural sector and in the broad economy, using a general equilibrium model of Brazil projected for poverty and distributional analysis. Of particular interest will be the social gains and the income distribution effects associated with the process.

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3 Technological change and growth: the general equilibrium approach

As noticed by Frisvold (1997) the general equilibrium approach to the technological change process differs from the traditional approaches of returns to investment in research that are focused, in general, in only one product, and in partial equilibrium. According to that author, the set of hypothesis used by those studies are restrictive in many aspects. In first place, they assume that prices and production of all other sectors are fixed. For example, it’s assumed that the changes in the production costs of corn won’t affect the prices of wheat of chicken meats.

This kind of hypothesis, however, can be too strong for technological progress phenomena broad enough to affect other productive activities at the same time. This is the case, for example, of a new kind of fertilizer or pesticide, which will affect simultaneously the productivity of many other agricultural activities. When just one sector is analyzed, typically only the supply curve of that sector is displaced, under the usual “ceteris paribus” conditions. The general equilibrium approach allows the relaxation of this hypothesis, allowing endogenous changes in prices and quantities of all the other sectors in response to the technological change (TC) in one sector.

Besides that, the general equilibrium (GE) approach makes it possible the joint analysis both of vertical effects (across activities placed at different levels of the commercialization chain, as is the case of agriculture and the food industry) and horizontal effects (between activities in the same level of the production chain), through the input-output relations in the economy, as well as the primary factors (labor and capital) markets.

The vertical effects relate to linkages between primary production and the input and product markets. In GE models these relations are explicitly modeled in the productive sphere of the model, where the production technology of all sectors is detailed. For example, in the model used in this study (the TERM-BR model) primary factors of production combine to create a composite primary factor through a Constant Elasticity of Substitution (CES) function which, for its turn, combine with other inputs produced by other production activities through a Leontief (fixed coefficients) function, to produce a certain level of output.

The horizontal effects are those linking the production activities through relation in production and consumption. In the production side the activities compete for primary factors (land, labor and capital), usually in limited supply. And, in the demand side, the production also substitutes in consumption between domestic and imported products, and in production for the domestic versus export markets. The GE approach takes explicitly into account all those aspects, and allows the understanding of the net results of many complex effects.

4 Methodology: the TERM-BR, a general equilibrium model for distributive effects

A computable general equilibrium (CGE) model of the Brazilian economy will be used to assess the economic and distributional impact of the Total Factor Productivity growth in Brazilian agriculture. The core CGE model is linked to a micro-simulation model of Brazil, and has its theoretical structure based on previous work of Ferreira Filho and Horridge (2006), Ferreira Filho, Santos and Lima (2007) and Ferreira Filho and Horridge (2008).

The model used in this paper is calibrated using a database for the 2004 year. It is based on the Brazilian National Accounts for 2004 and the Brazilian National Household Survey (Pesquisa Nacional por Amostragens de Domicílios – PNAD), for the year 2004 (IBGE, 2004). In what follows a description of the main features of the model is presented.

The core CGE model used here, the TERM-BR model, is a static inter-regional model of Brazil based on the TERM[2] model of Australia (Horridge, Madden and Wittwer, 2005). 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 classified according to wages, as a proxy for skills. The

[2] Versions of TERM have been prepared for Australia, Brazil, Finland, China, Indonesia and Japan. Related material can be found at www.monash.edu.au/policy/term.htm.

model distinguishes 42 producing sectors (or industries), among which 41 are single-product industries and the agricultural ("Agriculture") industry distributes its output (according to a Constant Elasticity of Transformation - CET constraint) between 11 agricultural commodities. 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[3]. Users of, say, vegetables in São Paulo state substitute between vegetables produced in the 27 states according to their relative prices, under a CES demand system[4].

With 27 regions, 42 industries, 52 commodities, and 10 labor types, the model contains around 1.5 million non-linear equations. It is solved (in linearized form) with the GEMPACK software. The CGE model is calibrated with data from two main sources: a 2004 Brazilian Input-Output Matrix[5], and some shares derived from the Pesquisa Agrícola Municipal (IBGE, 2004, available at http://ibge.gov.br).

On the income generation side of the model, workers are divided into 10 different categories (occupations), according to their wages. These wage classes are then assigned to each regional industry in the model. Together with the revenues from other endowments (capital and land rents) these wages will be used to generate household incomes. Each activity uses a particular mix of the 10 different labor occupations (skills). Changes in activity level change employment by sector and region. This drives changes in poverty and income distribution. Using the expenditure survey (POF, mentioned below) data the CGE model was extended to cover 270 different expenditure patterns, composed of 10 different income classes in 27 regions. In this way, all the expenditure-side detail of the micro-simulation dataset is incorporated within the main CGE model.

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[3] The dimensions of this margins matrix are: 52*2*2*27*27 [COM*SRC*MAR*REG*REG].

[4] For most goods, the inter-regional elasticity of substitution is fairly high. To ease the computational burden, we assume that all users of good G in region R draw the same share of their demands from region Z.

[5] The 2004 Brazilian Input-Output database used in this study was generated by the author based on the Brazilian National Accounting System tables (available at http://www.ibge.gov.br/servidor_arquivos_est/) , since the last official Input-Output table published by the Brazilian statistical agency if from 1996.

The micro-simulation model uses two main sources of information: the Pesquisa Nacional por Amostragem de Domicílios –PNAD (National Household Survey – IBGE, 2004), and the Pesquisa de Orçamentos Familiares- POF (Household Expenditure Survey, IBGE, 2006). The PNAD contains information about households and persons. The main information extracted from PNAD were wage by industry and region, as well as other personal characteristics such as years of schooling, sex, age, position in the family, and other socio-economic details.

The POF, on the other hand, is an expenditure survey that covers all the metropolitan regions in Brazil. It was undertaken during 2003, and covered 48,470 households, with the purpose of updating the consumption bundle structure. The main information drawn from this survey was the expenditure patterns of 10 different income classes, for all regions. One such pattern was assigned to each individual PNAD household, according to each income class. After preparation, the micro-simulation database comprises 283,363 persons (older than 15 years old) and 121,849 households.

The CGE and the micro-simulation (MS) models are run sequentially, with consistency between the two models assured by constraining the micro-simulation model to agree with the CGE model. The CGE model is sufficiently detailed, and its categories and data are close enough to those of the MS model that the CGE model predicts MS aggregate behavior (that is also included in the CGE model, such as household demands or labor supplies) very closely. The role of the MS model is to provide extra information about the variance of income within income groups, or about the incidence of price and wage changes upon groups not identified by the CGE model, such as groups identified by ethnic type, educational level, or family status. Note that each household in the micro data set has one of the 270 expenditure patterns identified in the main CGE model. There is very little scope for the MS to disagree with the CGE model.

The simulation starts with a TFP in Agriculture shock, and a new equilibrium calculated for 52 commodities, 42 industries, 10 households and 10 labor occupations, all of which vary by 27 regions. Next, the results from the CGE model are used to update the MS model. At first, this update consists basically in updating wages and hours worked for the 283,363 workers in the sample. These changes have a regional (27 regions) as well as sectoral (42 industries) dimension.

The model then relocates jobs according to changes in labor demand[6]. This is done by changing the PNAD weight of each worker in order to mimic the change in employment. In this approach, then, there is a true job relocation process going on. Although the job relocation has very little effect on the distribution of wages between the 270 household groups identified by the CGE model, it may have considerable impact on the variance of income within a group.

One final point about the procedure used in this paper should be stressed. Although the changes in the labor market are simulated for each adult in the labor force, the changes in expenditures and in poverty are tracked back to the household dimension. A PNAD key links persons to households, which contain one or more adults, either working in a particular sector and occupation, or unemployed, as well as dependents. In the model then it is possible to recompose changes in the household income from the changes in individual wages. This is a very important aspect of the model, since it is likely that family income variations are cushioned, in general, by this procedure. If, for example, one person in some household loses his job but another in the same household gets a new job, household income may change little (or even increase). Since households are the expenditure units in the model, we would expect household spending variations to be smoothed by this income pooling effect. On the other hand, the loss of a job will increase poverty more if the displaced worker is the sole earner in a household.

5 Poverty and income distribution in Brazil in the 2004 reference year

Despite the recent improvement, income in Brazil is still very concentrated. If household income is split in ten groups, as displayed in Table 1, it can be seen that the first five income household groups (POF 1 to POF 5), while accounting for 52.9% of population, get only 18.5% of total household income. The richest household, on the other hand, while accounting for just 10.9% of the population, get 43.7% of total household income.

[6] This methodology was named by the authors as “the quantum method” in previous work, and is described in more detail elsewhere (see Ferreira Filho. and Horridge, 2005). Here only the main ideas are presented.

Table 1. Poverty and income distribution in Brazil. 2004.

	Proportion of population	Proportion of income	Share bellow poverty line (FGT0)	Household Contributions to FGT0	Average poverty gap (FGT1)	Household contributions to FGT1
1 POF[1] (poorest)	14.2	2.2	0.86	0.14	0.53	0.09
2 POF[2]	14.1	4.1	0.64	0.09	0.19	0.03
3 POF[3]	20.9	9.9	0.20	0.04	0.03	0.01
4 POF[4]	7.5	4.7	0.04	0.00	0.01	0.00
5 POF[5]	11.1	8.4	0.02	0.00	0.00	0.00
6 POF[6]	7.3	7.0	0.00	0.00	0.00	0.00
7 POF[7]	9.8	12.7	0.00	0.00	0.00	0.00
8 POF[8]	5.3	9.3	0	0	0	0
9 POF[9]	4.7	12.1	0	0	0	0
10 POF[10] (richest)	5.2	29.5	0	0	0	0
National values	100.00	100.00	0.28	0.28	0.12	0.12
GINI	0.55					

The poverty line used in this study was set as one third of the average household income. Based on this poverty line about 28% of the Brazilian households would be poor in 2004, or about 15,611,871 out of 55,707,000 households[7].

The figures in Table 1 also show how each POF group contributes to the Foster-Greer-Thorbecke (1984) (FGT, for short) overall measures of poverty: FGT0 – the proportion of poor households (i.e., below the poverty line) and FGT1 – the average poverty gap ratio (proportion by which household income falls below the poverty line). It can be seen from Table 1 that the share bellow poverty line is very high until the third household income group, and that the poverty gap is very high among the poorest household group, around 53%. Actually, this household group contributes to almost 75% to the national poverty gap.

The poverty and income distribution figures also have important regional differences inside Brazil, a large country with important regional economic differentiation. These differences can be analyzed with the aid of the figures in Table 2.

Table 2. Regional poverty and income inequality figures. Brazil, 2004.

Regions	Macro-regions (*)	Regional population share in total population	Proportion of poor households in regional population (FGT0)	Regional contribution to total FGT0	Regional Average Poverty Gap (FGT1)	Regional Contribution to total Poverty Gap

[7] The criterion used in this study sets the value of the poverty line in R$184.66, in 2004 values. Note that this value is not directly comparable to most other studies in the field, since it is computed based on an equivalent income basis, and not as the average household income, as many studies do.

1 Rondonia	N	0.83	0.26	0.00	0.09	0.00
2 Acre	N	0.35	0.40	0.00	0.17	0.00
3 Amazonas	N	1.76	0.37	0.01	0.16	0.00
4 Roraima	N	0.21	0.44	0.00	0.22	0.00
5 Para	N	3.77	0.40	0.01	0.17	0.01
6 Amapa	N	0.32	0.39	0.00	0.17	0.00
7 Tocantins	N	0.71	0.34	0.00	0.13	0.00
8 Maranhao	NE	3.32	0.58	0.02	0.30	0.01
9 Piaui	NE	1.64	0.54	0.01	0.26	0.00
10 Ceara	NE	4.40	0.51	0.02	0.23	0.01
11 RGNorte	NE	1.64	0.47	0.01	0.21	0.00
12 Paraiba	NE	1.97	0.50	0.01	0.23	0.00
13 Pernambuco	NE	4.59	0.49	0.02	0.22	0.01
14 Alagoas	NE	1.65	0.57	0.01	0.27	0.00
15 Sergipe	NE	1.07	0.39	0.00	0.16	0.00
16 Bahia	NE	7.55	0.46	0.03	0.20	0.01
17 MinasG	SE	10.47	0.26	0.03	0.10	0.01
18 EspSanto	SE	1.85	0.25	0.00	0.10	0.00
19 RioJaneiro	SE	8.31	0.19	0.02	0.09	0.01
20 SaoPaulo	SE	21.88	0.16	0.04	0.07	0.02
21 Parana	S	5.59	0.17	0.01	0.07	0.00
22 StaCatari	S	3.19	0.10	0.00	0.04	0.00
23 RGSul	S	5.90	0.15	0.01	0.06	0.00
24 MtGrSul	CW	1.23	0.22	0.00	0.09	0.00
25 MtGrosso	CW	1.52	0.20	0.00	0.07	0.00
26 Goias	CW	3.04	0.22	0.01	0.08	0.00
27 DF	CW	1.25	0.22	0.00	0.11	0.00
Total	Brazil	100	-	0.28	-	0.12

*Macro-Regions: N = North; NE = North-East; SE = South-East; S = South; CW = Center-West

As it can be seen in Table 2, the most densely populated regions in Brazil are the Northeast region (NE), with 27.83% of total population, and the SE region, with 42.51% of total population in Brazil. The Northeast and North regions are those which present the higher relative poverty levels, or share of regional population bellow the poverty line. When one takes into account the size of the population, however, Sao Paulo and Minas Gerais, both in the Southeast regions of Brazil appear, side by side with Bahia, as the most important contributors to the national headcount ratio (FGT0)[8], as it can be seen from the fifth column in Table 2. Besides that, Sao Paulo is also the most important regional contributor to the poverty gap in the country.

[8] Sao Paulo and Minas Gerais are two of the most industrialized states in Brazil.

Table 3 and Table 4 bring more information regarding labor demand structure. Initially, Table 3 shows the structure of labor use by the production sectors in Brazil. In this table, the 42 industries have been aggregated to 5, for reporting purposes. The first line shows the upper limit, in year 2004 Reais, of the value of each wage class. For example, the wage class OCC2 includes monthly wages ranging from R$130 to R$225, and so on. The last wage class, OCC10, includes all monthly wages higher than R$1,500.00 in 2004 values[9].

As it can be seen in the table, Agriculture accounts for about 50.2% and 47.8% of total use (wages) of the less skilled (lowest wages) workers in Brazil, respectively wage classes OCC1 and OCC2, while the other sectors account for a larger share of workers in the higher wage classes. The Services sector is another important sector for the employment of the poorest.

Table 3. Use of labor by each aggregated activity. Shares. Brazil, 2004.

	Wage classes									
Sectors	OCC1	OCC2	OCC3	OCC4	OCC5	OCC6	OCC7	OCC8	OCC9	OCC10
Limit (R$)	130	225	260	300	390	480	600	800	1500	open
Agropec	0.502	0.478	0.169	0.213	0.172	0.128	0.107	0.075	0.051	0.059
ExtratMin	0.004	0.007	0.010	0.012	0.011	0.013	0.014	0.015	0.013	0.019
Manufact	0.067	0.051	0.093	0.100	0.136	0.164	0.159	0.157	0.147	0.125
FoodInd	0.023	0.026	0.038	0.040	0.046	0.046	0.042	0.036	0.028	0.014
Services	0.401	0.435	0.689	0.634	0.634	0.646	0.677	0.719	0.760	0.784
Total	1	1	1	1	1	1	1	1	1	1

Table 4 brings information about the income composition of the household income classes in Brazil (POF1 to POF10, after the Pesquisa de Orçamentos Familiares – POF, the expenditure survey), the expenditure units in the model. As it can be seen, the income of the poorest households is mostly composed of wages coming from the poorer workers. The income of the poorest household (POF1), for example, is almost entirely composed of wages coming from the three lowest wage groups, the less skilled workers in the economy.

This is an important aspect of the relation between TC in agriculture and its social impacts in Brazil. Agriculture pays a high share of the lowest wages in Brazil,

[9] For the sake of reference, the monthly weighted average value of the minimum wage in Brazil in 2004 was R$253.40 (4 months at R$240.0 and 8 months at R$260). Roughly speaking, then, OCC3 is around the limit of the minimum wage value. The PNAD reference month is September, when the minimum wage was R$260.00, which is the upper limit of the third wage group.

which concentrates in the poorest households, what creates a strong link, from the income generation side, from changes in Agriculture and changes in the income of the poorest households. This aspect will further explored later in this text.

Table 4. Household income composition according to worker's wage class. Brazil, 2004.

	1 OCC1	2 OCC2	3 OCC3	4 OCC4	5 OCC5	6 OCC6	7 OCC7	8 OCC8	9 OCC9	10 OCC10	Total
1 POF[1]	0.244	0.333	0.404	0.019	0	0	0	0	0	0	1
2 POF[2]	0.098	0.142	0.119	0.196	0.213	0.231	0	0	0	0	1
3 POF[3]	0.049	0.105	0.127	0.095	0.11	0.146	0.268	0.1	0	0	1
4 POF[4]	0.028	0.063	0.102	0.07	0.091	0.134	0.215	0.249	0.048	0	1
5 POF[5]	0.019	0.05	0.061	0.053	0.078	0.121	0.215	0.169	0.233	0	1
6 POF[6]	0.01	0.036	0.04	0.043	0.064	0.101	0.167	0.188	0.351	0	1
7 POF[7]	0.004	0.017	0.022	0.025	0.037	0.064	0.114	0.134	0.427	0.156	1
8 POF[8]	0.002	0.011	0.013	0.014	0.024	0.04	0.085	0.095	0.35	0.368	1
9 POF[9]	0.001	0.004	0.006	0.007	0.009	0.019	0.041	0.052	0.235	0.627	1
10 POF[10]	0	0.001	0.002	0.002	0.003	0.005	0.011	0.014	0.073	0.89	1

(*) – POF1 is the poorest, POF10 the richest.

6 The simulation: technological change in the Brazilian agriculture

The high rate of TC in many sectors is a noticeable feature of the Brazilian economy in the last years. Bonelli and Fonseca (1998) found, for example, for the period 1970/1997 a rate of growth of the Total Factor Productivity (TFP) of 1.7% a year for the aggregate of the economy. If only the 1995/1997 period is considered, however, that rate increases to about 2.75% a year what, according to those authors, would explain about 90% of GDP variation in the period.

The high increase in PTF in agriculture was documented by Gasques et al (2004), who found an annual rate of 4.88% for the decade of ninety, a value which rises to 6.04% a year for the period 2000/2002. Even though not directly comparable, these two studies give some guidance for the simulations implemented in this paper. The scenario to be simulated here entails a differential gains in PTF for agriculture of 2% a year in relation to manufacturing. For a five years period, the value to be simulated is a 10% increase in TPF in the Brazilian agriculture, above the trend in the total economy, starting in the 2004 base year.

7 Model closure

A central feature of CGE models is the closure used. CGE models are large sets of equations representing an economy which, in general, don't have originally the same number of equations and variables. The choice of the endogenous/exogenous set of variables to make a solution feasible is called the "closure" of the model. This choice is crucial for the results, and gives the model a particular character, which represent's the modeler's view of how the economy works. The closure chosen for this study gives the model a short run flavor, given the 5 years period span to be simulated. The main aspects of the closure used are:

- The capital stock is kept fixed at sector level, with the rate of return to capital adjusting endogenously to variations in capital demand.
- In the labor market the closure is differentiated for skilled and non-skilled types of labor. For the 10 occupational categories of the model, the first 5 (less skilled workers) are deemed to be perfectly mobile between sectors and regions. For these workers national employment is a positive function of national real wages in the simulation, representing the existence of labor surplus in all regions of these types of workers. For the higher wage groups (the last 5 wage groups) the total supply of labor is considered fixed (exogenous) at national level. The adjusting variable in this market is the real wage only, which shall rise in expanding sectors in order to attract workers from contracting sectors.
- The model allows for limited substitution between different types of labor.
- The total land stock is fixed, and used only by the agricultural activities.
- The nominal exchange rate is the model's "numeraire".

In the above description of the way the economy adjusts the short run flavor is imposed through the fixed quantity of factors stocks, notably land, capital and skilled labor.

8 Measuring the social gains associated with TC in the Brazilian agriculture

In partial equilibrium models the gains of TC are usually evaluated through variations in the consumers and producers surplus. As mentioned before, these measures don't take into account the interdependence between the many markets in the economy. The CGE models, on the other hand, on recognizing explicitly the interdependence of those markets allow the calculation of broader measures of welfare variation, as is the case of the money metric measures of utility variation. Among the different possible choices, a useful measure is the Hicksian Equivalent Variation (EV) concept. Basically the EV measures the amount of income which would be equivalent, in welfare terms, to the change observed in the economy, or the TC in the case under study. In other words, the EV is meant to represent the amount of income that would have to be given to (or taken from) an agent after a policy shock to keep him at the original welfare position, but after the introduction of the shocks.

The consumer demand in the TERM-BR model is represented by the Linear Expenditure System (LES). The Money Metric Utility measure (MMU) must then be derived from the corresponding utility function. The utility function associated is the Stone-Geary function:

$U = \prod_i (C_i - \gamma_i)^{\beta_i}$, where $\sum_i \beta_i = 1$ and γ_i is the subsistence minimum of each good **i**, and C_i is the total consumption of each good. Given the utility function, the demand function is obtained through the income constrained maximization process, resulting:

$C_i(P,Y) = \gamma_i + \frac{\beta i}{P_i}\left(Y - \sum_i \gamma_i . P_i\right)$, where Y is the consumer's nominal income and P the price vector. The indirect utility function is obtained substituting the demand functions in the utility function, resulting:

$V(P,Y) = \left[Y - \sum_i \gamma_i . P_i\right] * \prod_i \left(\frac{\beta_i}{P_i}\right)^{\beta_i}$. And, finally, solving for Y the MMU function can be obtained:

$Y(P,U) = \prod_i \left(\frac{P_i}{\beta_i}\right)^{\beta_i} * U + \sum_i \gamma_i . P_i$. The EV then can be calculated as:

$EV = M\left(P_i^0, U(P_i^1, Y^1)\right) - Y^0$, where, substituting the expression for U and rearranging results:

$EV = \prod_i \left(\frac{P_i^0}{P_i^1} \right)^{\beta_i} . \left[Y^1 - \sum_i \gamma_i . P_i^1 \right] - \left[Y^0 - \sum_i \gamma_i . P_i^0 \right]$. The superscripts 0 and 1 represent the time periods before and after the policy shock. This is the formula to calculate the EV in the model[10].

9 Results

This section brings the results of the simulation. The sector aggregation to be used in this paper can be seen in Table 5, bellow.

Table 5. Sectors, products, occupations and regions.

Activities	Products	Margins	Occupations	Regions
Agriculture	Coffee, Sugar Cane, Rice, Wheat, Soybean, Cotton, Corn, Livestock, Natural Milk, Poultry, Other Agriculture	Trade	OCC1	Rondonia
MineralExtr	Mineral Extraction	Transport	OCC2	Acre
PetrGasExtr	Oil and gas		OCC3	Amazonas
MinNonMet	Non metallic minerals		OCC4	Roraima
IronProduc	Iron ore		OCC5	Para
MetalNonFerr	Non ferrous metals		OCC6	Amapa
OtherMetal	Other metals		OCC7	Tocantins
MachTractor	Machines and tractors		OCC8	Maranhao
EletricMat	Electric material		OCC9	Piaui
EletronEquip	Eletronic equipment		OCC10	Ceara
Automobiles	Automobiles			RGNorte
OthVeicSpare	Other vehicles and spare parts			Paraiba
WoodFurnit	Furniture and lumber			Pernambuco
PaperGraph	Paper and graphic			Alagoas
RubberInd	Rubber products			Sergipe
ChemicElem	Chemical elements			Bahia
PetrolRefin	Petrol Refinery			MinasG
VariousChem	Other chemical products			EspSanto
PharmacPerf	Pharmaceuticals			RioJaneiro
Plastics	Plastics			SaoPaulo
Textiles	Textiles			Parana
Apparel	Apparel			StaCatari
ShoesInd	Shoes and leather products			RGSul
CoffeeInd	Processed coffee			MtGrSul
VegetProcess	Vegetable processing			MtGrosso
Slaughter	Processed animal products			Goias
Dairy	Dairy			DF
SugarInd	Sugar			
VegetOils	Vegetable oils			
OthFood	Other foods			
VariousInd	Other industries			

[10] Actually, the model uses a linearized version of this formula.

PubUtilServ	Public utilities services			
CivilConst	Civil construction			
Trade	Trade			
Transport	Transport			
Comunic	Communications			
FinancInst	Financial institutions			
FamServic	Services to households			
EnterpServ	Services to business			
BuildRentals	Dwellings			
PublAdm	Public administration			
NMercPriSer	Non mercaltile private services			

As mentioned before, the scenario to be analyzed comprises a 10% increase in PTF in the Brazilian agriculture, under the specified set of hypothesis about the factors markets closure. In what follows the results of the simulation are presented. Initially, Table 6 brings the results of some selected macroeconomic variables.

Table 6. Model results, selected macroeconomic variables.

Variable	% variation
Real household consumption	1.13
Government comsumption	0
Exports “quantum” index	2.78
Imports “quantum” index	0.24
Real GDP	1.13
Average Real wage	1.01
Aggregated employment	-0.01
Consumer Price Index	0.02
GDP deflator	0.11
Exports price index	-0.57
Imports price index	0
Land price	-4.44

As it can be seen from the above table, the simulated shock is important enough to generate aggregated impacts in the model. The increase in TFP expands the production possibility frontier of the economy, allowing an expansion in GDP. The results show a 1.13% increase in real terms. This increase is obtained through increases in household consumption (from the expenditure side) and in exports. With given CIF import prices and nominal exchange rate value (numeraire) the terms of change vary by exactly the same amount of the exports price index, meaning that the TFP change in agriculture generates a fall in the terms of trade.

The average real wage increases, while aggregate employment remains almost constant (a slight decrease). It's worth to remember that the labor market closure fixes the aggregated quantity of skilled labor. The increase in the real wage, then, is mostly due to the increase in the skilled workers wages, which increase more than the Consumer Price Index (CPI). These results can be seen in Table 7, bellow.

Table 7. Model results. Wages and employment, by occupational class. Percent variations.

Wage class	Nominal wage	Real wage	Employment
OCC1	-1.33	-1.25	-0.63
OCC2	-1.01	-1.01	-0.51
OCC3	0.32	0.27	0.14
OCC4	0.06	0.00	0.00
OCC5	0.31	0.24	0.12
OCC6	1.33	1.26	0
OCC7	1.47	1.40	0
OCC8	1.53	1.46	0
OCC9	1.63	1.55	0
OCC10	1.04	0.96	0

As it can be seen, employment variations occur in the first five occupational groups, or the less skilled workers, with a fall in employment of the less skilled due to the TC in agriculture. This fall happens mainly due to a fall in employment of this type of workers in agriculture, since this sector is responsible, in the database, for about 50.2% of the national wage bill of the lowest wages in Brazil (OCC1) in 2004 (see Table 3).

The increase in TFP in agriculture increases the real GDP, as expected. This increase, however, does not translate in uniform increases among all producing activities. As it can be seen in Table 8 , the level of activity of agriculture increases by 8.69%, while employment falls by 2.54% in the same sector. Note that this is the only one sector where both activity level and employment vary in opposite directions, what is due to the TC.

Table 8. Model results, sector variables. Percent variation.

Sector	Activity level	Employment	Production cost
Agriculture	8.69	-2.54	-11.21
MineralExtr	-0.25	-1.12	0.05
PetrGasExtr	-0.47	-1.49	0.14
MinNonMet	-0.25	-0.51	0.48
IronProduc	-0.36	-1.43	-0.03
MetalNonFerr	-0.39	-1.41	0.01
OtherMetal	-0.35	-0.71	0.41
MachTractor	-1.00	-1.54	0.34
EletricMat	-0.53	-0.95	0.44
EletronEquip	-0.87	-1.45	0.39

Automobiles	-0.25	-0.30	0.52
OthVeicSpare	-1.43	-2.00	0.32
WoodFurnit	0.15	0.29	0.28
PaperGraph	0.14	0.30	0.44
RubberInd	-0.23	-0.42	0.21
ChemicElem	0.29	1.10	-0.73
PetrolRefin	-0.01	-0.04	0.37
VariousChem	-0.58	-1.14	0.23
PharmacPerf	-0.07	-0.15	0.55
Plastics	-0.17	-0.26	0.62
Textiles	0.95	1.79	-0.10
Apparel	0.63	0.72	0.62
ShoesInd	0.39	0.46	0.04
CoffeeInd	1.17	1.98	-1.93
VegetProcess	6.70	12.16	-3.42
Slaughter	8.41	16.83	-3.09
Dairy	6.08	6.92	-6.00
SugarInd	2.33	7.70	-0.86
VegetOils	3.20	13.96	-0.92
OthFood	1.64	2.92	-2.12
VariousInd	0.10	0.19	0.71
PubUtilServ	0.09	0.43	1.45
CivilConst	-0.05	-0.09	0.76
Trade	-0.04	-0.06	0.99
Transport	-0.16	-0.25	0.84
Comunic	0.11	0.46	1.44
FinancInst	0.29	0.60	1.50
FamServic	0.51	0.64	0.67
EnterpServ	-0.23	-0.33	0.87
BuildRentals	0.02	0.46	2.00
PublAdm	0.00	0.00	1.01
NMercPriSer	1.09	1.13	0.69

*- Only intermediate inputs, does not include primary factors costs.

Agriculture produces in the model eleven commodities, with different production variation outcomes, as can be seen in Table 9. In this table, the last column shows the total value exported of each commodity as a share of total use in Brazil in 2004. As it can be seen, coffee, wheat and soybeans have significant shares of their total use exported in that year. Not by coincidence these are the commodities that expand production the most, given the high export elasticity assumed in this study. The other commodities, which are directed more to the domestic market, show a smaller increase in production.

Table 9. Agricultural commodities. Production and export variation %) and exported share.

Commodity	Production	Exports (value)	Exported share in total use
Coffee	13.90	24.95	0.54
SugarCane	2.79	-	0.01
PaddyRice	6.57	-	0.00
Wheat	14.57	29.75	0.21
Soybean	12.61	27.65	0.38
Cotton (in seed)	4.48	-	0.01
Corn	5.85	39.51	0.12
Livestock	8.91	49.52	0.04

NaturMilk	6.84	-	0.00
Poultry	9.50	22.61	0.06
OtherAgric	7.85	47.74	0.05

Notice also that the food industry in general experiences a strong push in its activity level, as well as a reduction in its production cost (Table 8). This illustrates the fact that the gains in TFP in agriculture are transmitted in the commercialization chain, benefiting the other sectors which have in agricultural products its main inputs.

The above results suggest that labor composition in the economy must change after the shock, since different sectors have different labor demand structure, which still varies across regions. The simulation results for regional employment and regional Gross Domestic Product (GDP) can be seen in Table 10.

Table 10. Regional employment and GDP. Percent variation.

Region	Employment	Regional GDP
Rondônia	-0.06	0.75
Acre	-0.24	0.31
Amazonas	-0.01	0.67
Roraima	-0.43	0.24
Para	0.08	0.83
Amapá	0.19	0.93
Tocantins	-0.06	0.78
Maranhão	0.17	0.87
Piauí	0.21	1.10
Ceara	0.25	1.68
Rio Grande Norte	-0.05	0.62
Paraíba	0.05	0.83
Pernambuco	-0.02	0.90
Alagoas	-0.57	0.31
Sergipe	0.05	0.81
Bahia	-0.15	0.49
Minas Gerais	0.07	1.17
Espírito Santo	0.30	1.68
Rio de Janeiro	-0.11	1.04
São Paulo	-0.12	1.18
Paraná	0.50	2.58
Sta. Catarina	0.11	1.77
Rio Grande Sul	0.02	1.31
Mato Grosso Sul	-0.02	1.28
Mato Grosso	0.37	2.20
Goiás	-0.23	0.97
DF	-0.12	1.39

The results for employment at regional level are a wage bill weighted average of employment variation at industry level in each region. As it can be seen from Table

10, the results are mixed, with some states increasing and others decreasing employment. This net result depends on the labor composition in each activity, as well as on the share of each activity in the regions. Note also in the same table that regional GDP increases in every state, even in those where there is a fall in employment, and increases more in those states where agriculture has a relatively higher share in total regional value added.

It was seen before in Table 7 that the fall in employment happens mainly in the less skilled labor types, what is, of course, a consequence of the structure of labor demand in agriculture. This is, then, a clear example of the effects of technological progress in a sector which demands proportionately more unskilled labor than the other sectors in the economy. The increase in the TFP in agriculture tends to save all production factors, but proportionately more the more intensive in use, generating a negative distributive effect (as will be seen later).

In terms of social gains evaluation, however, there is still another effect which must be taken into account, namely the variation in the price of food which, as is well known, accounts for an important share of the consumption bundle of the poorest households. Being the consumption bundle particular to each income group, a specific analysis for each income group is required in order to correctly include this effect. The model allows this calculation, since the consumption bundle by type of household is explicitly modeled with information from the Expenditure Surveys (POF). The results can be seen in Table 11.

Table 11. Income variation by household income group. Percent variation.

Income group	Nominal income	Consumer Price Index	Real income
POF[1]	2.00	-1.17	3.17
POF[2]	0.10	-0.99	1.09
POF[3]	0.27	-0.74	1.01
POF[4]	0.56	-0.53	1.09
POF[5]	0.71	-0.46	1.17
POF[6]	0.90	-0.33	1.23
POF[7]	0.96	-0.13	1.09
POF[8]	1.00	0.1	0.9
POF[9]	0.95	0.01	0.94
POF[10]	0.78	0.24	0.54

As discussed before, household income is calculated in the model tracking back from the individual incomes after the policy shock, aggregating to each household the income of all the workers belonging to it[11]. As it can be seen in Table 11 the household nominal income increases in all income groups, irrespective to the fall in employment observed previously[12].

The second column in the table shows the household specific Consumer Price Index. As it can be seen, the lower income households, which usually expend a large share of their income on food, show a larger fall in the CPI, due to the increase in PTF in agriculture. This doesn't happen in the three highest income groups, which show a positive variation in CPI. But the real income variation, which is the difference in the percentage increase in the nominal income and the CPI, is positive for all households.

Model results show, then, that even though the TFP increase in agriculture reduces the employment of the least skilled (and poorest) occupational group in Brazil, the benefits generated by the fall in prices and the general equilibrium employment effects on the economy tend to overcome that effect. Model results, then, point to a generalized gain in the economy. Again, this is a general equilibrium effect that can be only captured in this kind of models.

The above information can also be analyzed from a regional perspective, as shown in Table 12.

Table 12. Model results. Nominal income, Consumer Price Index and Real Income, by region. Percent variation.

Region	Nominal income	Consumer Price Index	Real Income
Rondônia	0.46	-0.32	0.78
Acre	-0.16	-0.34	0.18
Amazonas	0.16	-0.43	0.59
Roraima	-0.28	-0.36	0.08
Para	0.35	-0.55	0.90
Amapá	0.60	-0.49	1.09
Tocantins	0.26	-0.27	0.53
Maranhão	0.06	-0.66	0.72
Piauí	-0.11	-0.60	0.49
Ceara	0.58	-0.16	0.74
Rio Grande Norte	0.30	-0.33	0.63
Paraíba	-0.23	-0.60	0.37
Pernambuco	-0.25	-0.44	0.19
Alagoas	-1.58	-0.44	-1.14
Sergipe	0.05	-0.52	0.57
Bahia	-0.15	-0.40	0.25

[11] The PNAD database allows identifying the link between persons and households.
[12] Remember that the household income is an add-up of different occupational wage groups, as shown in Table 4. Besides that, one of the hypothesis of this work is that government transfers to households, which in 2004 accounts to 19.7% of total household income and is concentrated in the poorest, is updated (increases) by the nominal GDP growth. This is, of course, an arguable hypothesis.

Minas Gerais	0.84	-0.02	0.86
Espírito Santo	1.75	0.37	1.38
Rio de Janeiro	0.85	0.29	0.56
São Paulo	0.91	0.16	0.75
Paraná	1.93	0.44	1.49
Sta. Catarina	0.90	0.15	0.75
Rio Grande Sul	0.66	-0.03	0.69
Mato Grosso Sul	1.01	-0.10	1.11
Mato Grosso	1.55	0.06	1.49
Goiás	0.72	-0.11	0.83
DF	1.15	0.54	0.61

The results above turn evident the compositional effect of the regional consumption bundle over the real incomes. The price of the consumption bundle tends to fall more in the North and Northeast regions of Brazil, since in these regions there is proportionally a concentration or poor households, whose members are counted among the lowest occupational wage groups. It's in these regions, then, that the fall in the price of food has greater influence upon the real incomes. In the other regions of the country, where the higher income households concentrate relatively more, the CPI actually increases, as is the case of the states of Sao Paulo, Rio de Janeiro, Paraná and Santa Catarina. This effect is caused by the increase in the price of the other (non-food and imported) goods in the consumption bundle, a general equilibrium effect caused by the TFP increase in agriculture. Still, it calls attention the results for Alagoas state, where the (negative) nominal income effect dominates the price bundle effect, generating a fall in regional real income. This result is particular linked to the sugar cane production, which in the database is responsible for about 7% of total state value of production, and is relatively intensive in the least skilled workers.

And, finally, as mentioned before, the use of a CGE model allows the calculation of broad money metric measure of welfare variation, specifically the Hicksian Equivalent Variation (EV). This measure is a synthesis of all the multiple effects generated by the PTF increase in agriculture, a net welfare measure caused by the policy shock in the economy. The simulated 10% increase in TPF in agriculture, then, would be associated to a R$12,996.00 millions gain in 2004 values. This amount would correspond to 0.67% of the Brazilian GDP in 2004[13], or a gain of about 0.11% of GDP per year. According to the EV definition this would be the money value that would keep the economic agents in Brazil in the same welfare level if the TFP in

[13] The value of the Brazilian GDP in 2004 was R$1,937,183 millions.

agriculture did not have happened in the way it was simulated here. This gain would be around R$2.6 billions per year. As a yardstick for comparison, the budget of Embrapa in 2004 was R$923 millions, a value which falls to R$740 millions in the 2000-2004 period average.

This is a high social gain. Of course, not all of it can be attributed to the research in science and technology in Brazil, since part of those gains arises as a result of spillovers from investments in other countries. It can be expected, however, that a substantial share of those gains are associated to the domestic investments in research. Still to give a perspective for those values, Araujo et al (2002) estimated that the return to investment in research in the Sao Paulo state is around R$12 for each R$1 invested. This value is close to that found by Griliches (1975) for the American agriculture. Evenson, Pray and Rosegrand (1999), however, found a lower value of R$5 to R$6 for India.

10 Poverty and income distribution results

As discussed previously, the micro-simulation model uses information from PNAD and allows the tracking of the effects of TC in Agriculture on poverty and income distribution in Brazil. The results can be seen in Table 13.

Table 13. Poverty and income distribution results. Percent variation.

Household Income class	Average real income	GINI Index	Proportion of poor households (headcount ratio)	Average poverty gap (FGT1)
1 POF[1]	2.00		-0.70	-0.31
2 POF[2]	0.10		-0.39	2.49
3 POF[3]	0.27		-1.40	10.04
4 POF[4]	0.56		9.91	42.25
5 POF[5]	0.71		27.97	97.08
6 POF[6]	0.90		196.58	896.91
7 POF[7]	0.96		502.78	67559.20
8 POF[8]	1.00		0	0
9 POF[9]	0.95		0	0
10 POF[10]	0.78		0	0
Original values (base year)	-	0.55	0.28	0.12
Percentage change		0.35	-0.29	1.35

The results in Table 13 show how some income and poverty indicators in Brazil would change due to the simulated TFP in the Brazilian agriculture. As it can be seen, results show an aggregate fall in poverty (number of households bellow the poverty line, or headcount ratio), with a 0.29% reduction in the headcount ratio. This would amount to 45,162 less poor households, or less 189,059 people. The fall in poverty is more intense in the poorest households, and concentrates in the third household income group[14]. The poverty gap, on the other hand, also reduces for the poorest households, but increases for all the others. This is reflected in a 1.35% increase in the aggregate poverty gap, meaning that in average there is an increase in the distance of the average incomes of the poor to the poverty line. Interestingly enough, model results also point to a worsening of the GINI index, which is a measure of income distribution in the economy. This is associated to the fall in employment of the two least skilled (lowest wages) households, as shown in Table 7.

The results on poverty and income distribution can also be seen in regional terms, as shown in Figure 1. As it can be seen in the figure, the number of poor households actually increases in the poorest North and Northeast regions (except for Ceara and Rio Grande do Norte) , and decreases in the other regions. The aggregated result, then, is linked to the fall in poverty in the richest states in Brazil, as it can be seen from the absolute number of households leaving poverty in Sao Paulo, for example.

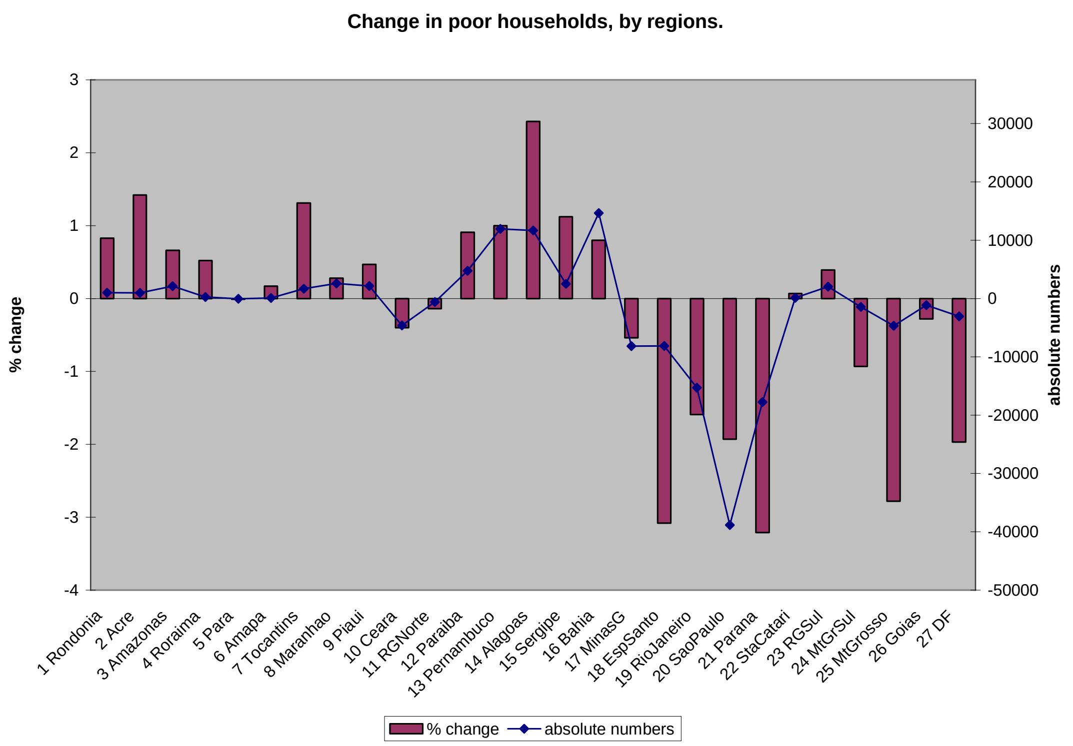

Figure 1. Model results. Change in number of poor households, by region. Percentage change.

[14] The very high numbers in poverty variation for households in class 4 and above are meaningless, since they represent a very high percent variation on a very small base value.

This is an important issue associated to the phenomenon, which, even though is poverty decreasing in aggregate, would tend to increase the actual regional employment disparities in Brazil.

This result, of course, could be different if different regional TFP change measures were used in the simulations. This information, however, is not available, but would be very important for a more refined analysis of the process. The same occurs with a more detailed description of the TC in Brazil. In this paper it is assumed to be Hicks neutral, or non-biased, what is also an arguable hypothesis. Field observation suggests that TC in Brazil is actually labor saving, and is likely to vary regionally, depending on a myriad of variables and circumstances.

11 Final remarks

As discussed in this paper, the TFP increase in agriculture has complex general equilibrium effects which distribute unevenly between the different actors in the society. The results here found suggest some points of particular interest.

Initially, it was shown that the employment of the less skilled workers would be negatively affected by the change, what is caused by the particular labor demand structure in the Brazilian agriculture. This is an extremely important aspect of the problem, and deserves a little more attention. The technological shock applied to the model is neutral (non-biased) from the standpoint of factor use. The dynamic activities in the Brazilian agriculture, however, appear to demand, in the dynamic regions, relatively less low skills labor and more high skills labor than in the less dynamic regions. This observation suggests that, in fact, the technological progress in the Brazilian agriculture is labor saving, and not neutral. Even though this hypothesis raised before by Ferreira Filho (2004) still demands more empirical assessment, its consequence would be a worsening of the negative effect here observed for the less skilled employment.

Another aspect associated to the abovementioned is related to the spillover of the TFP increase in agriculture to the other sectors in the economy. Just as the agricultural sector, the other sectors in the upstream position in the commercialization chain (food and other sectors to which agricultural inputs are important) would also be benefited in terms of increasing their activity level. On the contrary of agriculture, however, these sectors would show an increase in their employment levels, compensating in part the fall observed in agriculture.

Model results for employment are mixed across regions, with some states increasing aggregate employment and other states decreasing. The aggregated regional results, however, hide the fact that the effect on employment is particularly negative for the less skilled workers in every state, with important falls in the Northeast regions, the poorest in the country. The TFP in agriculture is transmitted through the commercialization chain, promoting also a regional redistribution of income, given the heterogeneity of the spatial distribution of the economic activity in the Brazilian territory. With the food and agricultural related industries concentrated in the South-Southeast Brazil, one of the effects of the TFP in agriculture is to decrease less qualification jobs employment in agricultural regions and increase more qualified employment in regions where food and agricultural related industries are concentrated.

Despite this last aspect of the problem, the results here found suggest that the positive net effect of the TFP increase in agriculture on welfare would be caused mainly by the fall in food prices, which would benefit the poorest the most. Actually, as shown by Alves (2004) the technological change in the Brazilian agriculture induced by the research system has had important role in the reduction of food prices in the country.

And, finally, it’s worth noting that the approach used in this paper doesn’t take into account the frictional effects of the adjustments in the labor market, which are important in reality. As a static model, the results show the final state of the economy in comparison to the initial one, but give important hints regarding the consequences of TFP increase in the Brazilian agriculture. This phenomenon reduces the employment of the unskilled workers proportionately more than the other types of workers, and this happens not as a consequence of biased technological change (not simulated here), but due to the labor demand structure in agriculture. With TC the agricultural sector will demand less and less unskilled workers, and would reduce its role as the most important employer of that kind of labor.

The issue of which policy instruments should be used to accommodate that phenomenon becomes relevant in a medium run perspective. Policies that turn labor a less expensive production factor would assume a prominent role here. This is especially true for the less skilled labor groups, which are better substitutes for capital (machinery and equipment) in the production process. Skilled labor is, in a certain sense, complementary to capital and modern production techniques, what can be inferred by the particular production structure of some activities in the traditional and dynamic agricultural regions. In this context, the question of adaptation of the Brazilian legal system to cope with this aspect of the problem would constitute a research program in itself, and the hypothesis to be examined would be to what extent is the labor legislation distorting the relative prices of labor and capital in Brazilian agriculture.

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