Possible regional impacts of agricultural trade liberalization in Brazil: some insights based on the estimation of soybean supply function

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Abstract

An important debate exists on whether soybean expansion in Brazil is responsible for putting more pressure on the Amazon forest or if it allows land use intensification through the recuperation of degraded pasture. In this paper, we estimate regional soybean supply own and cross price elasticity in order to better assess the possible impacts of agricultural trade liberalization in old and new soybean production basins. Applying a panel data estimation technique, we find large substitution supply elasticity between soybean and beef in Brazil Moreover, own price elasticity of soybean supply is much higher in *Cerrados* regions that in the South of the country. These results allow to discuss possible regional consequences of soybean trade liberalization on the Amazon forest. The current movements to promote sustainable and responsible soybean production in Brazil could certainly modify the future response of the sector to trade liberalization and its long term impacts.

1 Introduction

Brazil is one of the leaders in regional and multilateral trade negotiations, and particularly offensive on agricultural issues. Indeed one of the obvious comparative advantages of the country relies on its huge land and natural resources reserves, already partly responsible today of the competitiveness of some major agri-chains such as livestock, soybean or sugar. The expected price and export demand increase following possible larger market access in developed and developing countries may have very large economic impacts for the country.

However, in a large country as Brazil, the possible responses to market access increase and their impacts will probably strongly differs from one region to another. Indeed as stated by Thery (2005), the dynamism of the Brazilian agriculture is constantly reorganizing the national territory. Indeed, several agricultural commodities are concentrated in some specific regions.

This paper will focus on soybean, one of the major Brazilian agricultural commodities that could benefit from trade liberalization. It is based on a study aimed at estimating a soybean supply function for Brazil, and particularly its regional own price and cross price elasticity[1]. Estimating regional soybean supply elasticity allows making a preliminary qualitative analysis on where, and with what possible consequences, soybean expansion may occur, if trade liberalization leads to a significant price increase. Because of a strong differentiation of the regional distribution of soybean expansion in Brazil and of data limitations, a panel database has been built based on state-level official statistics.

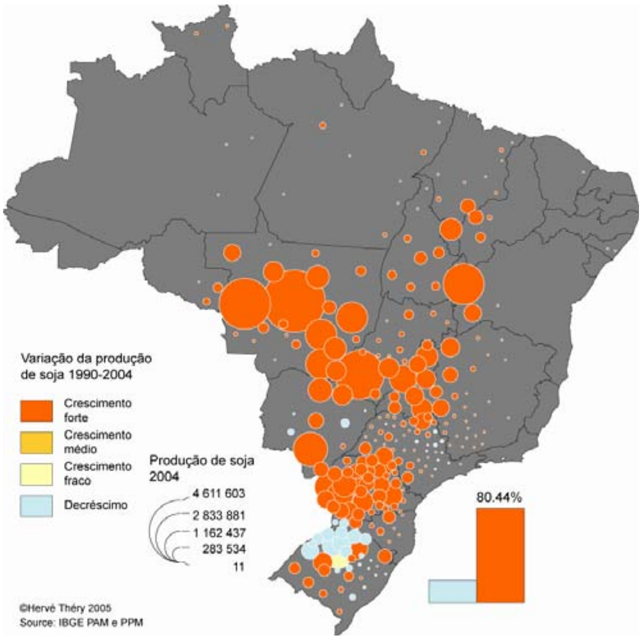
The paper will first present some apparent determinant of soybean expansion during the last fifteen years in Brazil (section 2). Then, the database and the methodology will be detailed (section 3). The results will be presented at the national and the regional levels (Section 4) and then the conclusion (section. 5).

2. Soybean expansion during the last 15 years in Brazil

The soybean planted area in Brazil has known a tremendous growth from around 250 000 hectares in 1960 to 16,3 millions hectares in 2004. Such expansion started in the South of the country, mainly in the States of Rio Grande do Sul and Parana during the 1960s, then continued through some states of the Centre-West (Minas Gerais, Goias and Mato Grosso do Sul) during the 1970s and the 1980s, and finally from 1990 until now, through the Northern of the *Cerrado*[2] region (Mato Grosso particularly, Northern part of the State of Tocantins and Maranhão, Southern Part of the Para State), at the frontier with the Amazon basin (Bertrand and al. 2004 - see Map 1.).

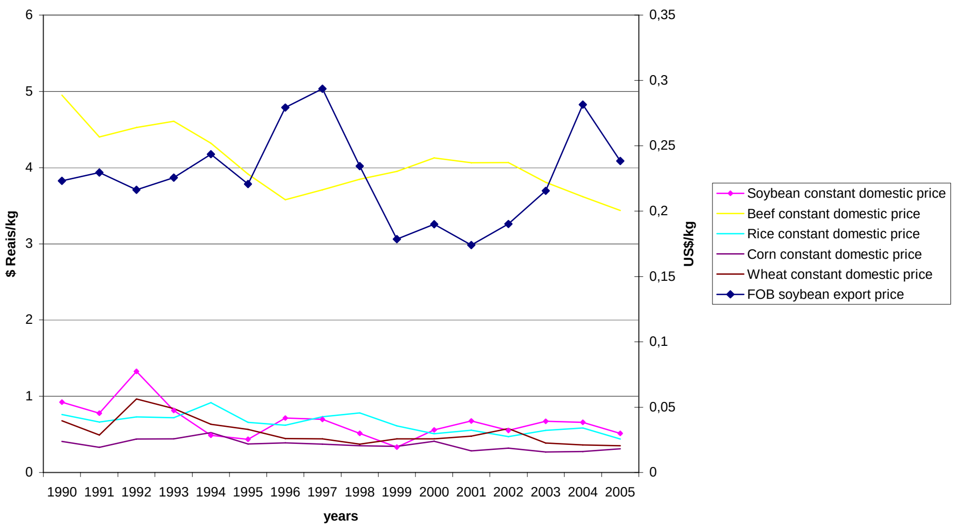
[1] This study was conducted in the context of the EU-Mercopol project (www.eumercopol.org), aimed at providing ex-ante impact analysis of agricultural trade liberalization between Europe and Mercosul.countries.
[2] For the graph exposed in the report, most of the *Cerrado* region pertains to the Centro Oeste macro region.

Map 1 : The expansion of soybean production in Brazil during the 1990s (Source Thery 2005)



In front of such an expansion particularly during the last 15 years, the first possible determinants coming in mind are exports or domestic output prices or the relative price of soybean vs. others agricultural products. However, such prices have not clearly favored soybean expansion as shown in Graph 1, so other determinants have to be invoked and, amongst them, regional land price, public research and exchange rates are possible good candidates (Bertrand and al. 2004).

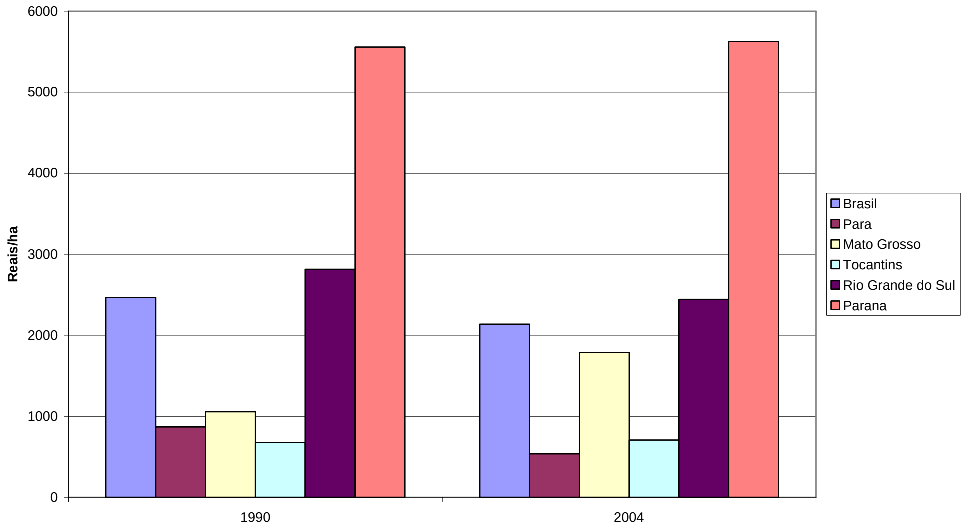
Graph 1 : Soybean, rice, wheat, corn and prices - 1990- 2005



Source : IBGE www.ibge.com.br

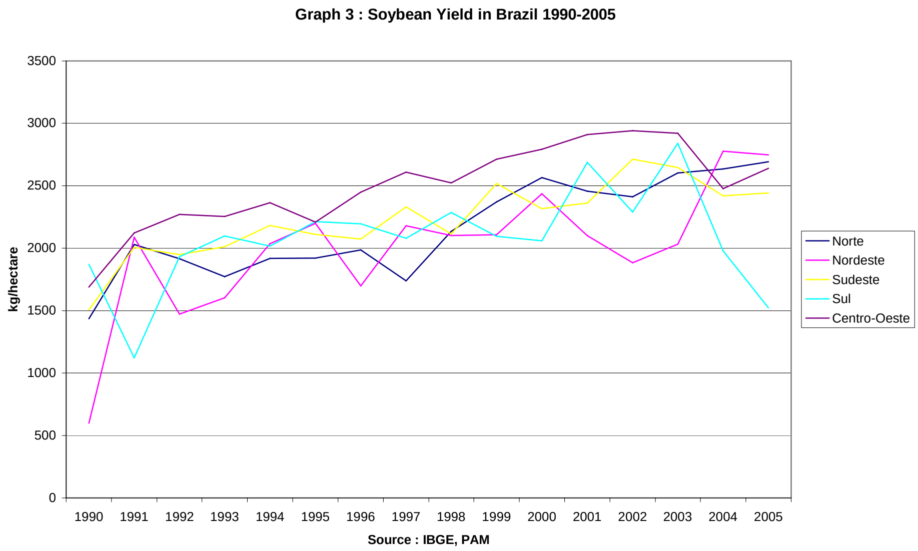
The *Cerrado* region, where most of the soybean expansion has occurred during the last 15 years, has been colonized during this period by migrants first essentially from the Southern part of the country then from closer states. The huge availability of land and low land prices have been the first determinants of such migration, as farmers could sell a property of 150 - 200 hectares in the South and acquire 800 to 1000 hectares in the States of the *Cerrados* region (Bertrand and al. 2004). Of course, in the meantime, this has led to an increase of land prices in the region but, the differential still persists (see graph 2), and, somewhere, it has reinforced the migration dynamic, attracting actors more interested by land speculation in a region where land rights and land property are not clearly defined. The low land prices in the *Cerrado* region is one of the main reason for which soybean is more competitive than in United States or in Argentine, even if such competitiveness is partially offset by higher transport costs to maritime ports (Bertrand and al. 2004). The Brazilian Program to improve roads in the region is aimed at lowering this constraint in the future.

Graph 2 : Land prices (pasture) 1990 and 2004 ($Reais 2004)



Source : fgvdados.com.br

Public research has also been an important vector of soybean expansion, since it has allowed the development of the culture in a region that was not adapted to former soybean varieties and agricultural technologies. Since the end of the 1970s, genetic research has allowed producing a variety adapted to the Cerrado regions, and several techniques have been developed to improve soils fertility. Such results led to yield improvements in all Brazilian States and particularly in the *Cerrados* region (see Graph 3).



Source : www.ibge.com.br

During the years 2000, between 40 % and 60 % of soybean grain production value came from exportation to the international markets. So exchange rate matters. Until the last years, the Brazilian real low rate has clearly favored exportations. The contrary occurred during 2004-2005, because of the US$ decrease, leading to reduce international selling and explaining, together with yield decrease, the current diminution of planted areas. Compared to other countries, the impact of exchange rate may be partially offset by the large size of the domestic market.

In term of substitution/complementarities with other agricultural activities, one can expect substitution with beef, since a significant share of soybean plantation are established on former pasture land. Substitution may be observed with rice also, as the soybean production and marketing chains presents several advantages when compared to the rice's one. For corn, the expect result is less clear because of the possibility to make a double harvest soybean / corn, with a small harvest of corn, during the same year. In effect, around 75 % of the area planted is summer corn production mainly produced in the Sates of Parana, Minas Gerais and Rio Grande do Sul and around 25 % of the area planted is winter corn production. The state of Mato Grosso is the largest winter corn producing state, corn being planted after soybean in a common rotation.

3. Methodology

3.1. Available data

The collection of most of the data linked to the agricultural sector in Brazil is made by IBGE, the Brazilian Statistics Institute (www.ibge.com.br). Two main database sources could have been used for this study: the Agricultural Census, realized every five years since 1970, which contains several detailed information (production volume, farming structures, areas etc…) and the Municipal Agricultural Production Survey, realized yearly since 1990 only, which contains data limited to planted and harvested areas, production volume and yield, and production value (producer price level). The main problem with the Agricultural Census is that the last available year is 1995-1996 and that, for several regions, data collection suffered various bottlenecks. Thus, the second database has been used, even if it does not contain very long term series (only 15 years).

For prices data (crops and beef price, land price and labor prices, inflation rate), the data from the foundation Getulio Vargas have been used (www.fgvdados.com.br). They are usually mensal and nominal, available at the national and the states levels, so some computations have been made to get annual constant prices for each Brazilian state.

For export FOB prices, the data comes from SECEX, the Secretary of Foreign Trade (www.aliceweb.desenvolvimento.gov.br), which computes yearly export volume and export values for each Brazilian imported and/or exported commodity. These data are also available at the States Level which allows having an estimation of each state export prices and share (% of the state production).

3.2. Supply function

A correct specification of supply response derived from the theory of production requires that the estimated supply function be homogeneous of degree zero in prices, including the price of both competing crops and important factors, and make explicit the role of fixed factors (Sadoulet and Janvry, 1995, cap.3). The profit function is the more rigorous theoretical specification but it requires a lot of data. The advantage of the Nervolian model is to pay attention to the mechanisms of price expectation formation and of partial adjustment in production. The better of two approaches needs to be integrated. How this is done depends on the objectives of the analysis and the data availability, seeking to strike a balance between rigor and convenience. Most Nervolian specifications offer a very large body of interesting empirical results (Sadoulet and De Janvry 1995).

A central problem in the estimation of the supply response equation derived from the theory of production is that farmers respond to expected prices. Usually, the observed prices are market or effective farms-gate price after production has occurred, while production decisions have to be based on the prices farmers expected to prevail several months later at harvest time. Because of the time lag involved in agricultural production, modeling the formation of expectation is thus an important issue in the analysis of agricultural supply.

The desired area to be allocated to a crop *i* in period *t* (A_{it}^d) is a function of expected relative prices (p_{it}^e) and a number of shifters, fixed factors, and truly exogenous variable such as weather:

$$A_{it}^d = \alpha_1 + \alpha_2 p_{it}^e + \alpha_3 z_{it} + \varepsilon_{1it} \qquad (1)$$

where ε_{1it} is the unobserved random factor.

Because a full adjustment to the desired allocation of land may not be possible in the short term, the area adjustment is only a fraction δ of the desired adjustment:

$$A_{it} = A_{it-1} + \delta(A_{it}^d - A_{it-1}) + \varepsilon_{2it} \qquad (2)$$

where A_{it} is the actual area planted of the crop *i*, A_{it-1} lagged planted area of the crop *i*, δ is the partial-adjustment coefficient and ε_{2it} a random term with $\varepsilon_{2it}\left(0,\sigma^2_{\varepsilon_{2it}}\right)$

The structural form equations (1) and (2) yield the reduced form:

$$A_{it} = \theta_0 + \theta_1 A_{i(t-1)} + \theta_2 p^e_{it} + \theta_3 Z_{it} + \nu_{it} \qquad (3)$$

where :

$$\theta_0 = \delta\alpha_0;\ \theta_1 = 1-\delta;\ \theta_2 = \delta\alpha_2,\ \theta_3 = \delta\alpha_3$$
$$\nu_{it} = \delta\varepsilon_{1it} + \varepsilon_{2it}$$

The presence of the lagged dependent variable introduces autocorrelation in the error term. However, we cannot estimating (3) because the presence of unobservable variable p^e.

To deal with the price expectation structure, many authors[i] are using a rational expectation approach or Nerlovian adaptative expectation approach. The Econometric techniques specify a forecasting equation for p^e_{it} as an autoregressive moving average (ARMA) process of order (*p*,*q*) in past prices (Judge, Griffiths, Hill, Lutkepohl, & Lee, 1985), i.e.:

$$p^e_{it} = \sum_{m=1}^{m} \alpha_m p_{it-m} + \sum_{n=1}^{q} \gamma_n \varepsilon_{3it-n} \qquad (4)$$

Replacing (4) in (3) and specifying *p* = {1, 2} and and *q* = {1, 2},

$$A_{it} = \theta_0 + \theta_1 A_{i(t-1)} + \lambda_1 p_{it-1} + \lambda_2 p_{it-2} + \theta_3 Z_{it} + \xi_{it} \qquad (5)$$

Where: $\lambda_1 = \theta_2\eta_1;\ \lambda_2 = \theta_2\eta_2$ and $\xi_{it} = \theta_2\gamma_1\varepsilon_{3it-1} + \theta_2\gamma_2\varepsilon_{3it-2} + \nu_{it}$

The above model should be estimated applying a Vector Autoregressive (VAR) with impulse response technique. Recently instead of ARMA, Kanwar (2006) estimated an ARIMA process of order (*p, d, q*). Unfortunately, in many developing countries, time series database are not long enough to estimate a VAR model. However, panel data based on sub-national data (regional, state level….) are sometimes available, as in Brazil, allowing to estimate a Dynamic Panel Data. Sending k, the state-level index, we have:

$$A_{ikt} = \theta_0 + \theta_1 A_{ik(t-1)} + \lambda_1 p_{ikt-1} + \lambda_2 p_{ikt-2} + \theta_3 Z_{ikt} + \upsilon_{ikt} \qquad (6)$$

$$\upsilon_{ikt} = \mu_k + \xi_{ikt} \qquad (7)$$

with μ_k denotes the unobservable individual-specific effect, ξ_{ikt} denotes the remaining disturbance, $\mu_k \approx IID(0,\sigma^2_\mu)$ and $\xi_{ikt} \approx IID(0,\sigma^2_\xi)$. Substituting (7) in (6):

$$A_{ikt} = \theta_0 + \theta_1 A_{ik(t-1)} + \lambda_1 p_{ikt-1} + \lambda_2 p_{ikt-2} + \theta_3 Z_{ikt} + \mu_k + \xi_{ikt} \qquad (8)$$

The problem with such Dynamic Panel Data regression is that it presents two sources of persistence over time (see, Baltagi (2005)): Autocorrelation due to the presence of lagged dependent variables among regressors and individual effects characterizing the heterogeneity among states. Since the A_{ikt} is a function of μ_k, it immediately follows that A_{ikt-1} is also a function of μ_k. Therefore A_{ikt-1} is correlated with error term. This is enough to turn Ordinary Last Square (OLS) estimator biased and inconsistent even though u_{ikt} are not serially correlated. To solve this problem, one option could be to apply the fixed effect estimator (FE) that wipes out μ_k. However, the fundamental identification condition for this model to be estimated by FE is the strict exogeneity of explanatory variables, which is not satisfied because A_{ikt-1} and p_{ikt-m} are correlated with u_{ikt-1} by construction. Therefore for a panel where T is fixed, the FE estimator is biased and inconsistent[3].

An alternative to wiping out the fixed effect is the first difference (FD) transformation. In this case, correlation between the predetermined explanatory variables and the remaining error is easier to handle (see, Baltagi (2005), cap. 8). The first differences get rid of the μ_k and, in practice, this allows to use past, present and future values of the strictly exogenous variables to build instruments for the lagged dependent variables and other non exogenous variables, once the permanent effect has been cancelled after differentiation (Anderson and Hsiao (1981)). Anderson and Hsiao (1981) suggested instrumental variable (IV) estimation method to estimate the first differentiating model. However, Arellano and Bond (1991) argue that this method leads to consistent but not necessarily efficient estimates of the parameter because it does not make use of all the available moment conditions. Therefore, they proposed a generalized method of moments (GMM) procedure that is more efficient than IV. In this paper, we have used the Arellano and Bond (1991) technique to estimate our dynamic panel model found in (12).

3. 3. Estimation using Panel Data

Sadoulet and Janvry (1995, cap 4) suggest that the supply function and first order conditions can be estimated simultaneously using observed price variables either time series data or pooling of cross-section. However the time series shows little variability in fixed factor unless the series is very long. When the series is not long the panel data is necessary.

As was mentioned in the last section, Brazil is a large country and the soybean planted area is not spatially homogeneous i.e. there are a lot of regional characteristics influencing supply, that change between states but are fixed on time. These features need to be controlled in the regression model to avoid biases of the estimated coefficients. The supply response of soybean in Brazil was estimated by Barbosa (1986) using rational expectation techniques. The original contribution of this paper is to work with panel data and to estimate the soybean supply elasticity controlling for fixed effect.

The term panel data refers to the pooling of observation on a cross-section of 13 States over 15 years. Following Behrman (1968) the agriculture planting area is used as a proxy of production. The empirical representation of equation (9) is described below

$$\begin{aligned}\ln area_{ikt} = \beta_0 + \beta_1 \ln(area)_{ik,t-1} + \beta_2 \ln(soy\ \ price)_{ikt-1} + \phi_j \ln(substitute\ price)_{jkt-1} \\ + \varphi_m \ln(input)_{mkt-n} + v_{ikt}\end{aligned} \tag{9}$$

[3] However, it is worth emphasizing that only if $T \to \propto$ the FE is consistent for the dynamic error component model (see Nickell (1981)), unfortunately in our data base T is fixed and short.

Where k (1,…, *13*) denoting the Brazilian States with soy bean plantation and T (1,…, 15) denoting available years, we will assume that v_{kt} follows a one-way error component model

$$v_{kt} = \mu_k + u_{kt} \qquad (10)$$

with μ_k denotes the unobservable individual-specific effect, u_{kt} denotes the remainder disturbance, $\mu_k \approx IID(0,\sigma_\mu^2)$ and $u_{kt} \approx IID(0,\sigma_u^2)$. Substituting (10) in (9):

$$\begin{aligned} \ln area_{ikt} &= \beta_0 + \beta_1 \ln(area)_{ik,t-1} + \beta_2 \ln(soy\ \ price)_{ikt-1} + \phi_j \ln(substitute\ \ price)_{jkt-1} \\ &+ \varphi_m \ln(input)_{mkt-n} + \mu_k + u_{ikt} \end{aligned} \qquad (11)$$

Panel data suggests that states are heterogeneous and that it is possible to control this. Soybean supply is modelled as a function of the lagged planted area, soybean own lagged price, substitute products lagged prices, and others input prices that vary with state and time. However, a lot of variables affecting soybean supply may be time-invariant (μ_k) as, for example, land quality, climate, kind of soil, sun exposition, etc. These variables change among States but they are not expected to change much over time. When time-invariant (μ_k) variables are omitted in the model, the estimated coefficients are biased.

Another advantage of panel data is that they allow the researcher to better understand adjustments dynamic. These dynamic relationships are characterized by the presence of a lagged dependent variable among independent variables.

As suggested in previous section, to wiping out the fixed effect we used the first difference (FD) transformation. Taking (11) first differences:

$$\begin{aligned} \Delta \ln area_{ikt} &= \beta_0 + \beta_1 \Delta \ln(area)_{ik,t-1} + \beta_2 \Delta \ln(soy\ \ price)_{ikt-1} + \phi_j \Delta \ln(substitute\ \ price)_{jkt-1} \\ &+ \varphi_m \Delta \ln(input)_{mkt-n} + \Delta u_{ikt} \end{aligned} \qquad (12)$$

4. Results

4.1 National level

Equation (12) describes the soybean planted area as a function of nine sets of variables: the planted area lagged; the soybean price lagged, two soybean substitute products price lagged (corn and beef); and two input variables (salary, and land price) plus two control variable (exchange rate and lagged exportation). Usually, farmers are buying land at time *t-1* to plant at time *t*. Therefore, we are assuming that farmer does not only consider the current land price but also the land price of the last year.

As mentioned, the international market is important to determine the soybean supply. Therefore, we have use the exchange rate (R$/U$) and export share as control variables. We are assuming that farmers decide the size of the area to be planted in soybean after observing the lagged exchange rates.

Moreover, we consider that land price, soybean price, beef and corn prices are endogenous variables. Equation (12) is estimated using GMM with Instrumental Variables (IV) technique. Current and lagged prices are used as instrument (Arellano and Bond (1991) (AB)).The table 1 report three models: In the column (1) the equation (12) was estimated using one-step AB technique supposing all variable are exogenous except planting area lagged. In the column (2) the one step GMM with IV was estimated, because now we are supposing that land, soybean, corn and beef prices are endogenous variables. Finally in column (3) the GMM with IV was estimated with the coefficients robust to heteroskedasticity.

Interpreting table (1) column (1) the Sargan test from homoskedastic estimator cannot reject the null hypothesis that the overidentifying restriction is valid. However we reject the null hypothesis of no first-order autocorrelation in residuals, and we cannot reject the second-order no autocorrelation null hypothesis. First-order autocorrelation in residuals does not imply that estimates are inconsistent, just second-order autocorrelation. Estimating the model considering land, soybean, corn and beef prices as endogenous variables (table 1 column 2) improve the results. Now, the Sargan test once more cannot reject the null hypothesis that the overidentifying restriction is valid and we cannot reject the null hypothesis of no first-order and second-order autocorrelation in residuals. When the model presents a good specification, Arellano and Bond (1991) recommend using the one-step result for inference on the coefficient because the two step stand errors tend to be biased downward in small sample.

Appling the White matrix to heteroskedasticity correction (table 1, column 3) once more we cannot reject null hypothesis of no first-order and second-order autocorrelation. Comparing columns (2) and (3), standard errors are quit small in the column (3) what suggesting heteroskedasticity. However, the only important difference is that the beef price lagged coefficient becomes significant to 10% in model (3).

Analyzing the estimated coefficients in table 1 column (3), we observed that some coefficients are significant and have expected signs. The exchange rate first lagged coefficients are positive and significant, reflecting that the lower the Brazilian Real the larger the soybean planted area. However the exchange rate second lagged coefficient is negative and significant. It may be, because farmers are expecting an appreciation of the Real after two years of low values. Observing the expected the export participation and inputs coefficients (wage and land price), any one are significant at 5%. Beef and corn first lagged coefficients are negative and significant at 10% and 5% respectively, means that they probable be soybean substitute products. Because beef price lagged coefficients are bigger than corn coefficients beef price appears to have more impact than corn price on the size of the area planted in soybean. Finally, just the soybean first differences price lagged coefficients are positive and significant.

Table 1: Soybean Supply estimation
(Dependent variable is planted area)

	(1)	**(2)**	**(3)**
lnarea (t-1)	0.815	0.788	0.788
	(0.054)**	(0.049)**	(0.045)**
dlnp_soy(t-1)	0.204	0.197	0.197
	(0.041)**	(0.040)**	(0.054)**
lnp_soy(t-2)	0.018	0.031	0.031
	(0.039)	(0.038)	(0.019)*
dlnp_beef(t-1)	-0.265	-0.206	-0.206
	(0.191)	(0.184)	(0.128)*
lnp_beef(t-2)	-0.056	-0.087	-0.087
	(0.190)	(0.182)	(0.166)
dlnp_corn(t)	0.048	0.050	0.050

	(0.055)	(0.053)	(0.040)
lnp_corn(t-1)	-0.115	-0.093	-0.093
	(0.060)	(0.057)	(0.026)**
lnp_corn(t-2)	-0.093	-0.081	-0.081
	(0.055)	(0.052)	(0.059)
dlnp_pland(t-1)	-0.022	-0.018	-0.018
	(0.066)	(0.062)	(0.049)
lnp_pland(t-2)	0.004	0.020	0.020
	(0.055)	(0.053)	(0.047)
dlnwage(t-1)	0.020	0.014	0.014
	(0.039)	(0.035)	(0.026)
lnwage(t-2)	-0.009	-0.009	-0.009
	(0.024)	(0.022)	(0.017)
dln%fob(t-1)	0.020	0.017	0.017
	(0.013)	(0.013)	(0.012)
ln%fob(t-2)	0.003	0.000	0.000
	(0.007)	(0.007)	(0.004)
lnexenge(t-1)	0.078	0.066	0.066
	(0.027)**	(0.026)**	(0.018)**
lnexenge(t-2)	-0.063	-0.055	-0.055
	(0.022)**	(0.022)*	(0.012)**
Constant	0.025	0.030	0.030
	(0.011)*	(0.010)**	(0.008)**
Observations	117	117	117
Sargan Chi2 =	79.35 (0.758)	97.04 (1.000)	-
No autocorrelation order 1	-4.38 (0.000)	-4.44 (0.000)	-1.94 (0.053)
No autocorrelation order 2	-0.23 (0.818)	0.29 (0.774)	0.49 (0.630)

Obs: Standard errors in parentheses ** significant at 5%; * significant at 10%.

The column (3) is robust to heterocedasticity.

Using the estimated coefficients in table 1 column 3, it is possible to calculate the own and cross price supply elasticities for both models. The short supply elasticity is the price lagged estimated coefficient, and the long term elasticity is calculated admitting that in the long term *(t) = (t-1) (see table 2).*

In the long term, we can consider that soybean supply is elastic (1.08). Beef is an important soybean substitute with cross price elasticity near one (-0.97). On the other hand, analyzing the cross price elasticity with corn, it appears to be inelastic (-0.44). This may partially reflect that in some cases corn can also be a secondary crop after soybean, as stated in part 1, and such complementarity may partially offset the substitution effect at the national level.

Table 2: Own price and cross price supply elasticities. National level

	BRASIL	
	LT	**ST**
soybean	1.08	0.197
beef	-0.97	-0.206
corn	-0.44	-0.050

4.2. Regional Analysis

As stated in part 1, soybean production started in the South of Brazil, particularly in two states, Rio Grande do Sul and Parana, and then grew progressively in the Northern direction, until the Amazon boarders in the 1990s. So we can separate two different macro regions: the traditional and older one, in the South and Southeast States, where in some cases the planted area is decreasing, and the new and dynamic one, in the Center-West and *Cerrado* regions.

Our sample was divided in two parts. Region 1 is the Centre – West and *Cerrado,* and includes the States of Rondônia, Tocantins, Piaui, Mato Grosso, Matogrosso do Sul and Goias. Region 2 is the South and Southeast and includes the States of Minas Gerais, São Paulo, Paraná, Santa Catarina and Rio Grande do Sul

Tables 3 and 4 display the soybean elasticity for both regions 1 and 2 respectively. In both cases, the one-step GMM AB technique was used. As in table 1, the model (12) was first estimated supposing all variables exogenous (first column). In the second column, land, soybean, corn and beef prices are endogenous and the model is estimated using GMM with IV. Finally in the column 3, the GMM with IV was estimated again but with the coefficients robust to heteroskedasticity.

Analyzing the identifications conditions in tables 3 and 4; the overidentification null hypothesis is rejected even in column (1), it can be because the Sargan test is not powerful enough with small data. In both model the nulls hypothesis of second order no autocorrelation cannot be rejected. Once more, we are analyzing just the column (3) results because the coefficients are robust to heteroskedasticity.

Comparing Regions 1 and 2 (tables 3 and 4) planted area lagged and soybean price coefficients are significant and have expected signs. In both regions, beef and corn have coefficients different from zero. Beef appears to be soybean substitute but it is bigger in the C*errado*. On the other hand, corn is a soybean substitute just in the South. In *Cerrado* coefficient of first differences of corn is positive and coefficient of second lagged corn is negative but smaller. These results suggested that corn is a complementary soybean crop. For input coefficient, wage coefficients are significant but not with expected signs and land price lagged are not significant in both regions. Exchange rate coefficients are significant in both models and present the expected sign, whereas export participation is significant only in the *Cerrado*.

Table 3: Soybean Supply estimation in Brazilian *Cerrado*
(Dependent variable is planted area)

	(1)	**(2)**	**(3)**
lnarea (t-1)	0.799	0.799	0.799
	(0.083)**	(0.083)**	(0.038)**
dlnp_soy(t-1)	0.358	0.358	0.358
	(0.074)**	(0.074)**	(0.037)**
lnp_soy(t-2)	-0.037	-0.037	-0.037
	(0.068)	(0.068)	(0.035)
dlnp_beef(t-1)	-0.628	-0.628	-0.628
	(0.401)	(0.401)	(0.213)**
lnp_beef(t-2)	0.020	0.020	0.020
	(0.378)	(0.378)	(0.224)
dlnp_corn(t)	0.309	0.309	0.309
	(0.121)*	(0.121)*	(0.091)**
lnp_corn(t-1)	0.004	0.004	0.004
	(0.109)	(0.109)	(0.046)
lnp_corn(t-2)	-0.167	-0.167	-0.167
	(0.104)	(0.104)	(0.042)**
dlnp_pland(t-1)	0.035	0.035	0.035
	(0.115)	(0.115)	(0.040)
lnp_pland(t-2)	-0.039	-0.039	-0.039
	(0.097)	(0.097)	(0.031)
dlnwage(t-1)	0.095	0.095	0.095
	(0.082)	(0.082)	(0.042)*
lnwage(t-2)	-0.027	-0.027	-0.027
	(0.049)	(0.049)	(0.029)
dln%fob(t-1)	0.034	0.034	0.034
	(0.030)	(0.030)	(0.012)**
ln%fob(t-2)	-0.018	-0.018	-0.018
	(0.031)	(0.031)	(0.026)
Lnexenge(t-1)	0.077	0.077	0.077
	(0.048)	(0.048)	(0.020)**
Lnexenge(t-2)	-0.071	-0.071	-0.071
	(0.036)	(0.036)	(0.012)**
Constant	0.046	0.046	0.046
	(0.020)*	(0.020)*	(0.010)**
Observations	50	50	50
Sargan Chi2 =	27.30 (1.000)	27.30 (1.000)	-
No autocorrelation order 1	-3.00 (0.003)	-3.00 (0.003)	-1.45 (0.146)
No autocorrelation order 2	0.74 (0.460)	0.74 (0.460)	1.35 (0.177)

Obs: Standard errors in parentheses ** significant at 5%; * significant at 10%. The column (3) is robust to heterocedasticity.

Table 4: Soybean Supply estimation in Southern Brazil
(Dependent variable is planted area)

	(1)	(2)	(3)
lnarea (t-1)	0.700	0.700	0.700
	(0.094)**	(0.094)**	(0.098)**
dlnp_soy(t-1)	0.103	0.103	0.103
	(0.045)*	(0.045)*	(0.038)**
lnp_soy(t-2)	0.079	0.079	0.079
	(0.049)	(0.049)	(0.039)*
dlnp_beef(t-1)	-0.196	-0.196	-0.196
	(0.198)	(0.198)	(0.090)*
lnp_beef(t-2)	-0.162	-0.162	-0.162
	(0.227)	(0.227)	(0.212)
dlnp_corn(t)	-0.043	-0.043	-0.043
	(0.058)	(0.058)	(0.038)
lnp_corn(t-1)	-0.076	-0.076	-0.076
	(0.071)	(0.071)	(0.036)*
lnp_corn(t-2)	-0.015	-0.015	-0.015
	(0.069)	(0.069)	(0.078)
dlnp_pland(t-1)	-0.036	-0.036	-0.036
	(0.084)	(0.084)	(0.070)
lnp_pland(t-2)	0.050	0.050	0.050
	(0.067)	(0.067)	(0.069)
dlnwage(t-1)	0.011	0.011	0.011
	(0.034)	(0.034)	(0.004)**
lnwage(t-2)	0.021	0.021	0.021
	(0.024)	(0.024)	(0.023)
dln%fob(t-1)	-0.000	-0.000	-0.000
	(0.015)	(0.015)	(0.015)
ln%fob(t-2)	-0.010	-0.010	-0.010
	(0.014)	(0.014)	(0.003)**
lnexenge(t-1)	0.050	0.050	0.050
	(0.035)	(0.035)	(0.023)*
lnexenge(t-2)	-0.044	-0.044	-0.044
	(0.034)	(0.034)	(0.026)
Constant	0.031	0.031	0.031
	(0.012)**	(0.012)**	(0.013)*
Observations		58	58
Sargan Chi2 =	48.89 (1.000)	48.89 (1.000)	-

No autocorrelation order 1	-2.68 (0.008)	-2.68 (0.008)	-2.02 (0.044)
No autocorrelation order 2	0.30 (0.762)	0.30 (0.762)	-0.62 (0.538)

Obs: Standard errors in parentheses ** significant at 5%; * significant at 1%. The column (3) is robust to heterocedasticity.

The regions 1 and 2 long and short term own and cross price elasticity are found in table 5. For own price elasticity, a clear difference appears between both regions: the long term soybean supply is elastic in the Center-West region (1.60) and much higher than the soybean elasticity in the South-Southeast region (0.60), which was quite expected when one looks at the soybean expansion regional dynamic during the last 15 years.

In both regions beef appears as a soybean substitute. The substitution is much more easier in the *Cerrado* (-3,12) than in the South (-0.65). Corn appears as a substitute in the South, but as a complementary crop in the *Cerrados*, as expected. Corn is a soybean substitute crop (-0.25) in South and a soybean complementary crop (0.71) in the *Cerrados*.

Table 5: Own price and cross price supply elasticities
in Regions 1 (Center-West - *Cerrado*) and 2 (South-South_Eastern).

	I		II	
	LT	**ST**	**LT**	**ST**
Soybean	1.60	0.358	0.61	0.103
Beef	-3.12	-0.628	-0.65	-0.196
Corn	0.71	0.309	-0.25	-0.043

5. Conclusions and discussion

Estimating regional soybean supply elasticity shows that the agrichain possible response to trade liberalization will be quite contrasted between the South – South East and the Center West –*Cerrados* regions. It is clear that any international price increase may probably speed up the expansion of soybean in the *Cerrados*, as it occurred during the last 15 years, unless new determinants appears to restrain this movement.

One of them could be the growing concern of the possible negative impact of soybean expansion on the Amazon forest. Indeed, an important debate exists on whether soybean is responsible for putting more pressure on the Amazon forest or if it allows land use intensification through the recuperation of degraded pasture. On the one hand, Brandão and al. (2005) have argued that soybean was planted mainly on degraded pasture and did not affect significantly deforestation. On the other hand, the Forest Working Group of the Brazilian Forum of NGOs and Social movements for Environment and Development (FBOMS) has conducted a rapid analysis for the Brazilian Ministry of Agriculture, showing some correlation between soybean expansion and deforestation, particularly in Matto Grosso, mainly through the delocalization of ranching activities up to the Amazon frontiers. Probably both studies are right to some extent. More recently, based on satellite image analysis in the State of Mato Grosso, Morton and al. (2006) estimated that direct forest conversion for crop production amounts to a maximum of 25% of the total deforested area. It means that the main source of land for soybean expansion is still today pasture but that direct conversion of forest also occurs.

Our results at the national level suggest that beef and soybean are substitutes. Contrasting results are found between older soybean production basins (South and Southeast) and new soybean frontiers (Center-West). In the Amazon Border (Center – West), substitution between cattle ranching and soybean appears much easier than in the South. Corn and beef are both exported and larger market access may also increase these commodities international prices according to most prospective simulations based on world general equilibrium models. At the border of the Amazon, specific private or public regulations should be implemented to reinforce land use intensification through pasture-soybean-corn rotation.

Several soybean international firms, under strong NGOs pressure, have recently decided to put a moratorium on the buying of soybean from recently deforested areas in Brazil during two years. The Brazilian industry itself is engaged in negotiation with the civil society to establish criteria to promote sustainable and responsible soybean production. One of them, particularly important in the Amazon to conciliate the expansion of agriculture and environment preservation, is the respect of the legal reserve (80 % of the property in the Amazon Biome and 35 % in the *Cerrado* Biome). Still at the beginning, such movements will probably affect the Brazilian response to increase market access, as well as it long term impacts.

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