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Enhancing the Brazilian land use module in Aglink-Cosimo

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Executive summary

The primary objective of this report is to document the improvements made to the Brazilian module of the Aglink-Cosimo model (Enciso *et al.*, 2015; OECD-FAO, 2015) related to the inclusion of land use dynamics. Aglink-Cosimo is an agricultural partial equilibrium model developed by the Organisation for Economic Co-operation and Development (OECD) and the Food and Agriculture Organization of the United Nations (FAO) in partnership with some member countries of these organisations. It is a partial equilibrium model used to simulate the annual developments of supply, demand and prices for the main agricultural commodities produced and traded worldwide over a 10-year period. It is a recursive-dynamic model, since current economic decisions are reached by taking into account lagged information on prices and quantities.

Aglink-Cosimo is central to the integrated Modelling Platform for Agro-economic Commodity and Policy Analysis (iMAP) of the Joint Research Centre (JRC) of the European Commission. Its main objectives are the implementation of quantitative tools for commodity market and agricultural policy analysis, and the preparation of a benchmark for the assessment of agricultural policies in a medium- to long-term horizon (so-called 'baseline'). Models in iMAP are used in stand-alone mode or in combination, to address a broad range of topics linked to the economic assessment of agricultural and rural development policies, as well as those concerning related topics such as trade, energy, the environment and climate change.

The model improvements to the Brazilian module reported here are important to assess the effects of domestic policy changes on the economic performance of the Brazilian agricultural sector, but also to analyse how agricultural production and land use in Brazil would respond to changes in world market commodity prices (1). The utilised agricultural area in Brazil has increased in recent years, mainly driven by increases in multiple cropping and livestock density on pastureland. Here we propose a methodology to capture the multi-cropping aspect of Brazilian agricultural in Aglink-Cosimo and expand the crop coverage of the model to also include pasture land and beans. Moreover, to capture the changing livestock density on pastureland, a beef cow intensity function (i.e. cow inventory divided by land use) is estimated using historical data. Last but not least, the movement and allocation of crops within Brazil are discussed in relation to their distance from ports and the associated transport costs. Internal transport costs are included in the model as a relative discount to the export price depending on the distance from ports for specific crops.

To test the behaviour of the revised model, three illustrative scenarios are included in the report. A first scenario focuses on the economic impacts in the Brazilian agricultural sector of abolishing the biofuel blending mandates. In a second scenario, the land use effects of an intensification of cattle production in Brazil are analysed. Finally, a scenario on the reduction of transport costs between the State of Mato Grosso and the port of Santos for agricultural commodities due to better infrastructures is depicted, with a clear focus on balance of trade effects. These scenarios show that the land use response in Brazil is strongly linked to the world market. This is not surprising, since Brazil is an important exporter of agricultural commodities, for instance soybeans and beef. The proposed scenarios also demonstrate the importance of having a complete model such as Aglink-Cosimo to analyse direct and indirect land use changes.

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(1) This project has benefited from the in-depth knowledge of Silvia Kanadani-Campos, currently working at the Brazilian Agricultural Research Corporation (Embrapa), and the cooperation of Embrapa to improve the representation of Brazil in the Aglink-Cosimo model.

1 Background and rationale

The rainforest and land use change in Brazil have been a central point of attention for many people and institutions around the world during decades. Historically, area expansion played a key role in increasing agricultural production globally, but since the 1950s productivity gains have been mainly attributed to technological progress (e.g. use of 'land-saving' technologies or more productive breeds). An increased use of agricultural inputs and better access to irrigation and mechanisation have predominately explained the increase in global agricultural production (Goldewijk *et al*., 2011).

However, in Brazil, area expansion played a key role in boosting agricultural production, especially in the Centre-West Cerrado, Brazil's main producing region (Correa, 2013). In the period 1990 to 2009, area expansion explained 60 % and 80 % of the growth in soybean and sugar cane production respectively, with these crops holding back cattle grazing areas in the region. Regarding sugar cane production in the state of Goiás, the area expansion explains about 80 % of production growth.

This area expansion for sugar cane and soybeans continued during the period 2005-2015 (IBGE,2017). The expansion of area explains around 80 % (soybeans) and 90 % (sugar cane) of production growth in the country. However, the situation changed for maize and beans, since most of the production growth was attributed to increases in yields and multiple cropping (second crop for maize and third crop for beans). While the production from the first crop of maize remained almost stable from 2000 to 2015 (CONAB, 2017), the harvested area decreased 40 % and the yield increased by 70 %. At the same time, the production from the second crop of maize increased by more than 14 times (and the corresponding harvested area by 3.2 times). For beans (2), while the first crop production declined by 20 %, the production from the second and third crops increased by 23 %, with the harvested area declining by about 25 % and yields tripling.

A further expansion of soybeans and sugar cane areas is likely to happen, since currently new land is being brought into production, some natural pastures are being ploughed and other (less profitable) crops might be replaced.

Sugar cane production is expected to expand in all Brazil's traditional producer states, with the largest effects in Minas Gerais, Goiás and Paraná (Brazil, 2014). It is estimated that the cultivated area for arable crops in Brazil will increase by 15 % in the period 2014–2024, going from 70 million to 80 million hectares (FIESP, 2014).

Based on data from the Instituto Brasileiro de Geografia e Estatística (IBGE), pastures occupied about 170 million hectares of land in 2006, which corresponds to about 70 % of the utilised agricultural area (UAA) and 20 % of all Brazilian territory (IBGE, 2009). The cattle production system is mainly extensive with low density (Rivero *et al*., 2009; Ferraz and Felício, 2010). The herd size is estimated to be 212 million head of cattle (IBGE, 2017), of which 4 million are kept in feedlots (ASSOCON, 2015).

Moreover, to protect the rainforest, the recent implementation of the Forest Code forces a reduction in the deforestation rate in order to comply with the legislation. In this context, the analysis of livestock intensification (i.e. livestock units per hectare) becomes crucial. It is estimated that the pasture area will be reduced by 4.5 million hectares between 2014 and 2024 while beef production will grow by an average of 2 % a year during this period (Brazil, 2014). This represents an increase of approximately 25 % in production per hectare.

Another important driver of land use in Brazil is the production of biofuels around the world and its intensive use of feedstock materials (soybeans, corn, sugar cane, etc.). This has undoubtedly contributed to the expansion of arable crop production in Brazil.

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(2) Bean is sufficiently important in Brazil to require its incorporation in the land allocation system of Aglink, especially if the model will be used to determine indirect land use changes (ILUC).

2 Revision of the Brazilian module in Aglink-Cosimo to capture land use dynamics

2.1 Facts and figures

The total area of Brazil is 851 million hectares, most of which (65 %) is occupied by natural vegetation. Pasture land occupies 20 % of the territory, agriculture 8 % (IBGE, 2017) and urbanisation and other uses 4 % (see Table 1).

Table 1 Brazilian land use, 2014/2015

Land use	Area (million ha)		Percentage		Percentage of arable land	
Total	851		100			
Pastures (a)	167.6		20			
Agriculture (b)	*First crop*	*Other crops*				
TOTAL (75.7)	*62.3*	*13.4*	7			
Soybeans	32.2					
Maize	5.6	9.8				
Wheat (winter crop)		2.5				
Rice	2.1					
Beans	1.6	1.1				
Sugar cane	10.1					
Cotton	1.0					
Other temporary crops	4.0					
Permanent crops	5.7					
Urbanisation and other uses	38.0		4			
Arable land (c,d)	*World Bank*	*FGVAgro*	*World Bank*	*FGVAgro*	*World Bank*	*FGVAgro*
	284	329	33	39	100	100
Land use for agriculture (first crop + pastures)	230	230	27	27	81	70
Available land to agriculture (e)	54	99	6	12	19	30

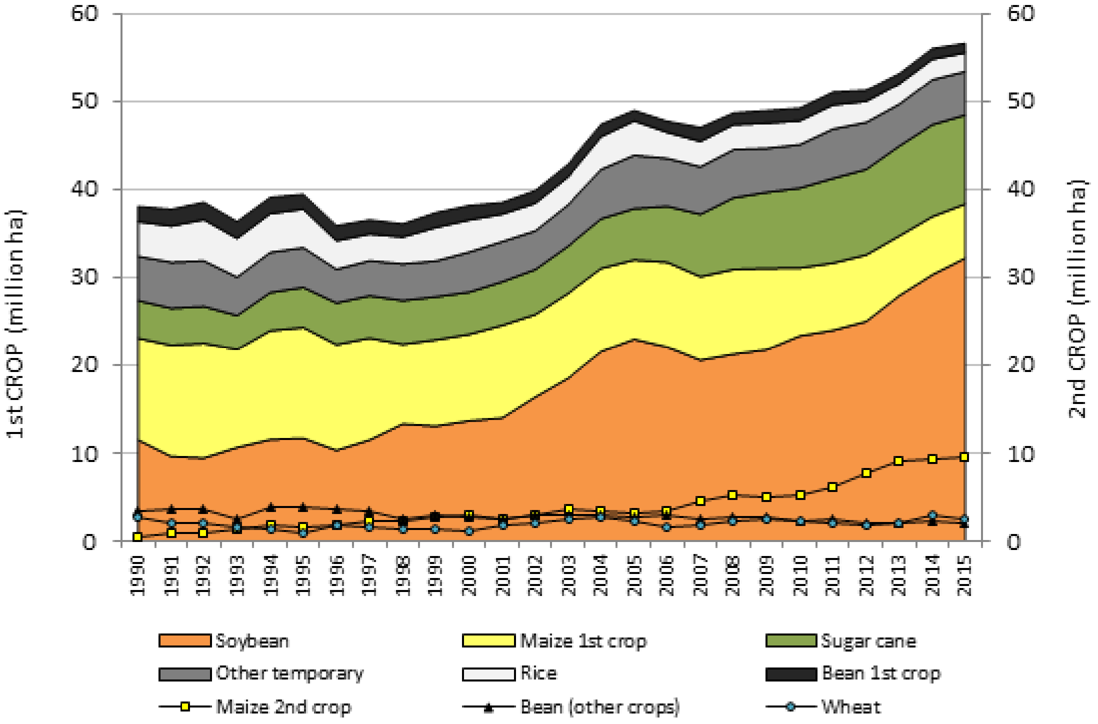
Sources: (a) Agroconsult (2016); (b) IBGE (2017); (c) FGVAgro (2014); (d) World Bank (2016); (e) estimated.

In 2014/2015, the agricultural crop area (excluding pasture land) covered 62.3 million hectares, with 13.4 million hectares being utilised more than once to grow wheat and both a second and third crop of maize and beans (multiple cropping). The crop with the largest area is soybeans, with 32.2 million hectares harvested in 2015, followed by maize, with 5.6 million hectares in the first crop and 10 million in the second crop.

Pasture area used for cattle grazing still dominates the UAA in Brazil, with 168 million hectares (Agroconsult, 2016), which is over 2.5 times the amount of land under arable crops. Clearly, further expansion of arable crop production is possible. Brazil's arable land is 284 million hectares according to the World Bank (2016) and 329 million hectares according to FGVAgro 2014. Considering that land use for agriculture is around 230 million hectares, we estimate that a further 50 million to 100 million hectares of arable land is available.
Of the total arable land of 328 million hectares (FGVAgro, 2014), around 19 % is still available to agriculture (Table 1).

Brazilian agricultural land use has changed over the years as demand for crops and animal products has increased (growing commodities exports, growth in biofuel feedstock and soybeans, beef exports etc.). Figure 1 shows this dynamic expansion in arable land use over the years. The harvested area of temporary crops in the first season has expanded from roughly 38 million hectares in 1990 to nearly 57 million in 2015 with a notable expansion of the area of soybeans and sugar cane. At the same time, the second crop (or multiple cropping) of maize and beans has grown and the size of the first crop has reduced(see Figure 2 about maize).

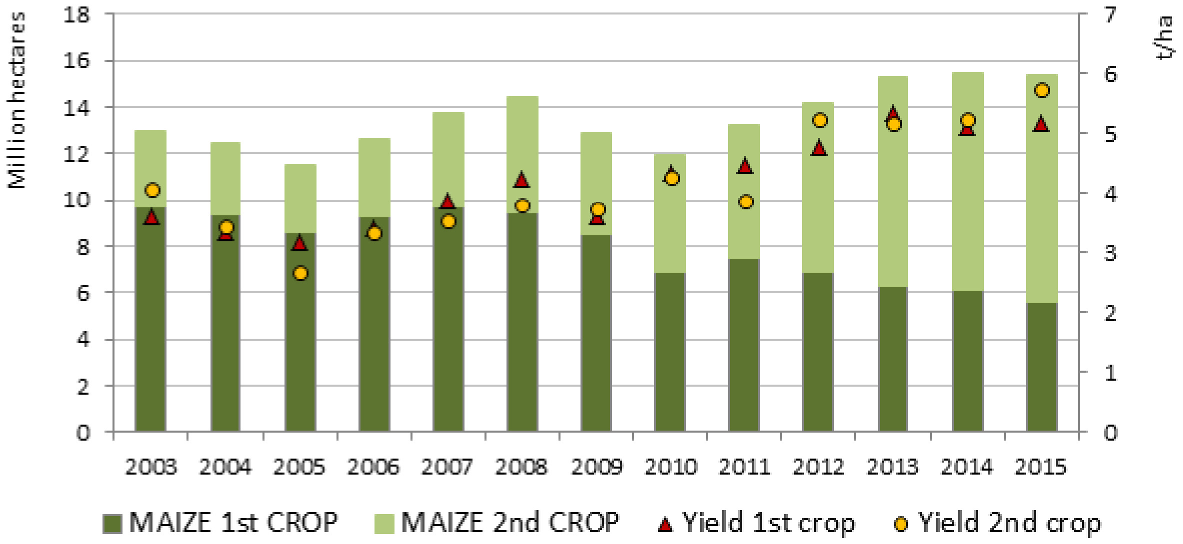
Figure 1. Agricultural land use in Brazil (2015)



Source: IBGE (2017) and CONAB (2017).

In 2003 the first crop represented more than 70 % of the total harvested area of maize. In 2015 the structure changed and the second crop was the main crop, with more than 60 % of the total harvested area of maize (Figure 2).

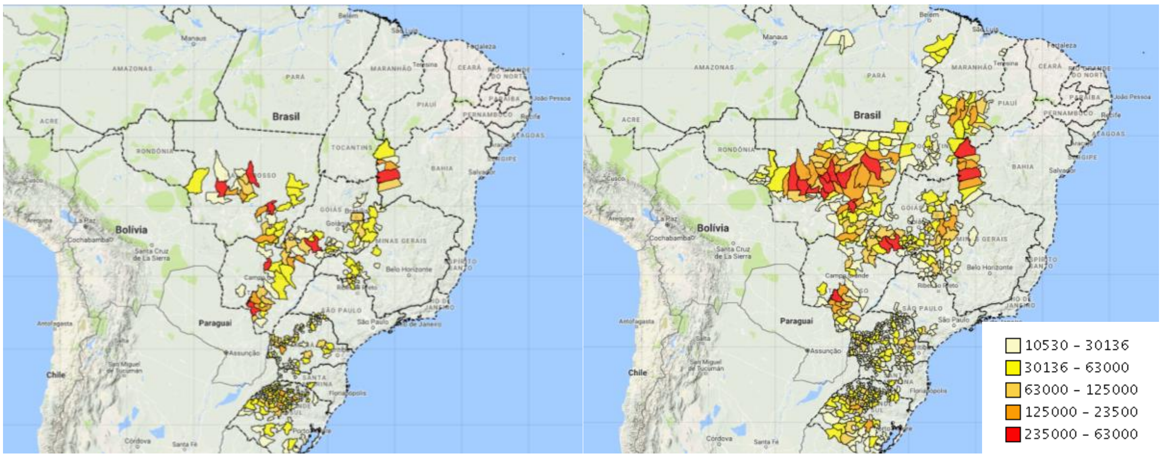
Figure 2. Maize: move from first to second crop



Source: IBGE (2017).

Figures 3 to 6 show the spatial distribution of soybeans, maize, cotton and rice production areas in 1990 and 2014. The total soybean area occupies more than 32 million hectares of the territory, representing more than 50 % of the agricultural area. Nowadays the soybeans are mainly produced in the states of Mato Grosso (27 % of the area), Rio Grande do Sul and Paraná (each 16 % of the area). The Northeast Cerrado (the region that comprises the states of Maranhão, Tocantins, Piauí and Bahia and is increasingly important in Brazil's agricultural production) covers 11 % of the total area.

Figure 3. Soybean harvested area in Brazil, 1990 (left) and 2014 (right)

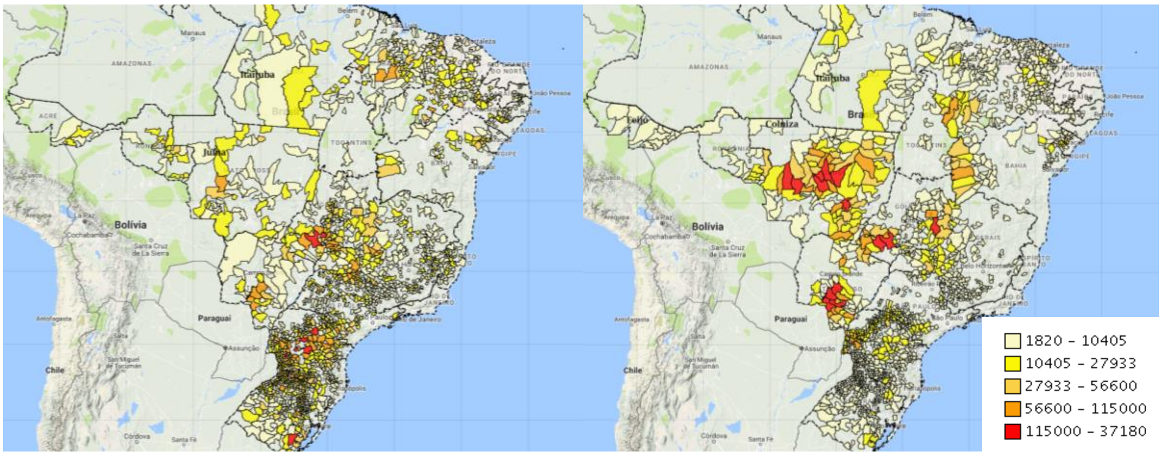


Note: The municipalities shown in the map represent 90 % of the main harvested area of soybeans in Brazil in 2014. The legend shows the harvested area of soybeans by municipality, in hectares.

Source: Somabrasil/Embrapa (2017).

Compared with other crops, maize has a wider distribution across all national territories due to its easy adaptation to diverse ecosystems and also due to its direct use as feed for livestock production. Figure 4 shows a concentration of maize production in the states of Mato Grosso (23 % of the total area), Paraná (15 %) and Mato Grosso do Sul (11 %) over the years.

Figure 4. Maize harvested area in Brazil, 1990 (left) and 2014 (right)

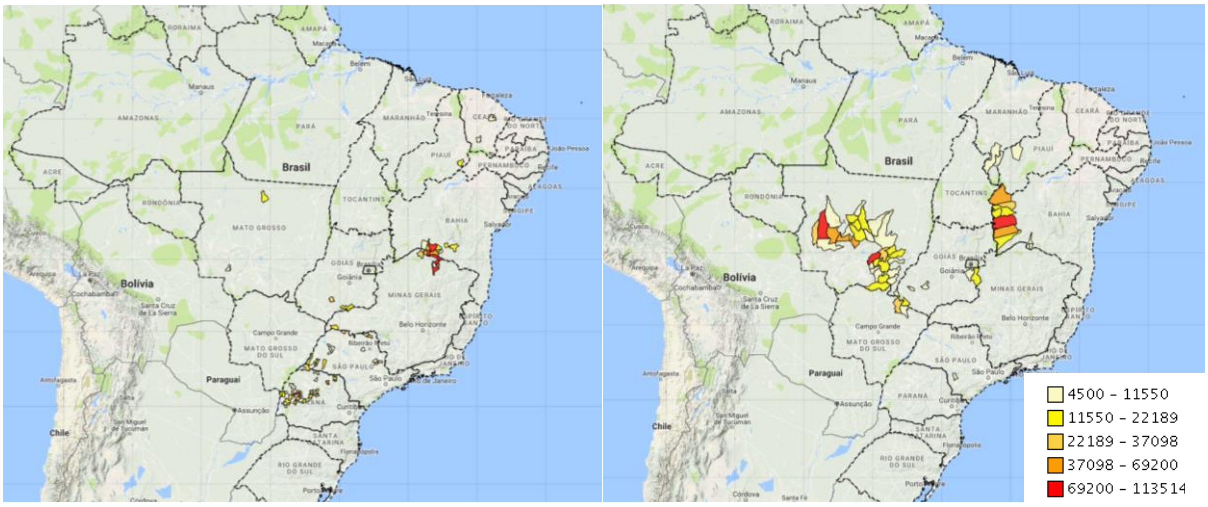


Note: The municipalities shown in the map represent 90 % of the main harvested area of maize in Brazil in 2014. The legend shows the harvested area of maize by municipality, in hectares.

Source: Somabrasil/Embrapa (2017).

The area under cotton in Brazil is about 1 million hectares (less than 2 % of the agricultural area), with the main producer states being Mato Grosso (56 % of the total cotton area) and Bahia (32 %). This is shown in Figure 5.

Figure 5. Cotton harvested area in Brazil, 1990 (left) and 2014 (right)

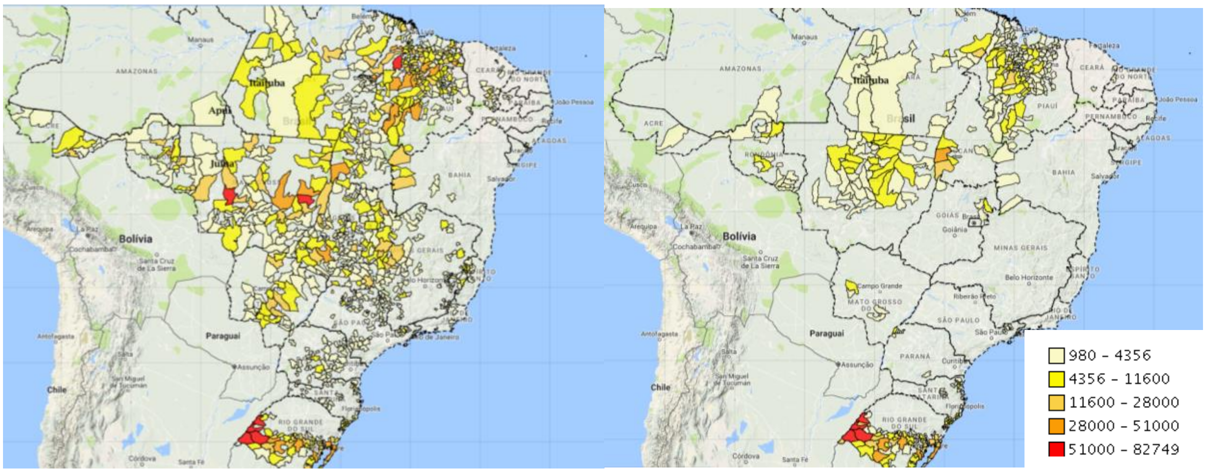


Note: The municipalities shown in the map represent 90 % of the main harvested area of cotton in Brazil in 2014. The legend shows the harvested area of cotton by municipality, in hectares.

Source: Somabrasil/Embrapa (2017).

Rice accounted for about 2 million hectares in 2014, with production mainly concentrated in the state of Rio Grande do Sul (50 % of the total rice area). Maranhão and Mato Grosso are also important rice producers, covering 11 % of the total area each. This is shown in Figure 6.

Figure 6. Rice harvested area in Brazil, 1990 (left) and 2014 (right)

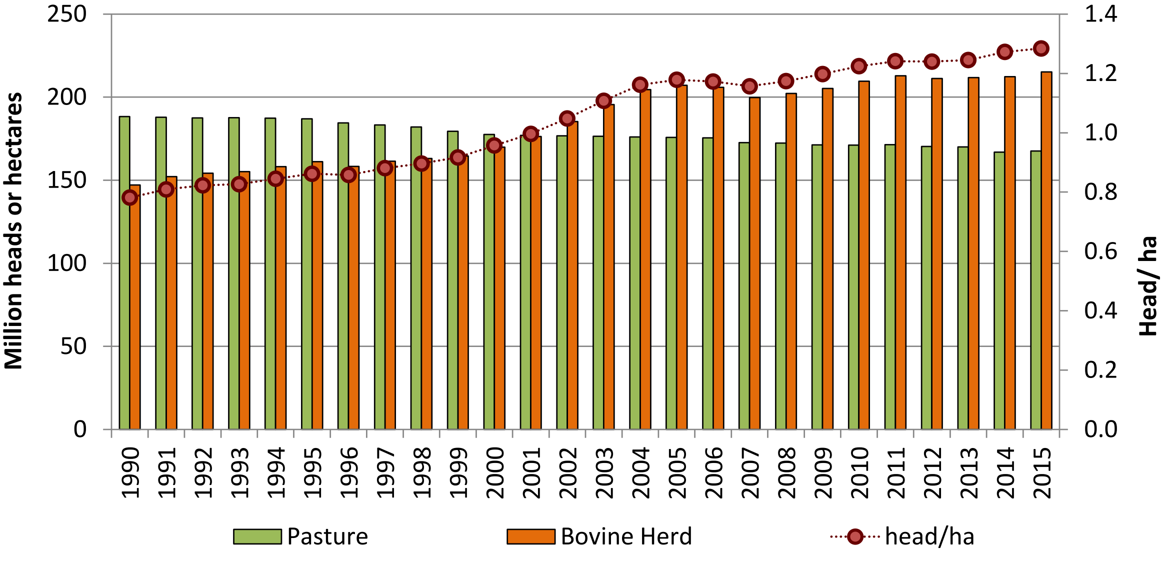


Note: The municipalities shown in the map represent 90 % of the main harvested area of rice in Brazil in 2014. The legend shows the harvested area of rice by municipality, in hectares.

Source: Somabrasil/Embrapa (2017).

The pasture area in Brazil has declined over the years from 188 million hectares in 1990 to 167 million in 2015, a reduction of about 20 million (Figure 7), which corresponds roughly to the increase in arable land use shown in Figure 1. Figure 7 also highlights the growth in cattle production and the increase in livestock density over time. This increase in livestock intensity could potentially imply an increase in land devoted to crop production (for feed). Increasing the livestock stocking density from 1.2 head/ha to 1.3 would release 12 million hectares of additional land available for crop production (if the herd size remained constant). However, if it increased to 1.5 head/ha, then 32 million hectares of land would be released for crop production.

Figure 7. Pasture land, cattle herd size and density



Sources: Agroconsult (2016) and IBGE (2017).

In summary, given the present representation of UAA within the Brazilian module of the Aglink-Cosimo model, a revision was deemed necessary to properly capture the land use dynamics just described: an increase in cattle production density over time will probably imply a sizeable expansion of arable crop production, which needs to consider competition for land between crops and pasture and the multiple cropping aspect of Brazilian agriculture. To capture these elements, the following adjustments have been made to the model:

- adding the multiple crop aspect (second crop) to the harvested land area and making a distinction between the land use area (first crop) and the harvested area (first + second crops);
- revising or estimating the own and cross land supply elasticities for both the first and second crops ([3]);
- updating the input proportions of all crops based on the latest cost-of-production calculations, allowing a revision of the commodity production cost indices in the Brazilian module of Aglink-Cosimo;
- adding beans and pastures in the first crop land allocation;
- adjusting the beef cow inventory supply function;
- incorporating the effect of internal transport costs on the domestic weighted average prices of soybeans, cotton, maize and rice.

2.2 Land use and multiple cropping

In the present Aglink-Cosimo model, the area harvested in Brazil is determined by the relative competitiveness of the different crops, with no distinction made regarding whether the area harvested is the first or the second crop on a given area of land. In the present Brazilian module the area harvested $(AH_{r,c,t})$ in country *r* for crop *c* in year *t* is determined by the 'doubled-log' equation (1) below.

$$\log\left(AH_{r,c,t}\right) = \alpha_{r,c} + \beta_{1,r,c}.\log\left(AH_{r,c,(t-1)}\right) + \sum_{i=1}^{8} \beta_{r,c,i}\,.\log\left(\frac{RH_{r,i,(t-1)} + EPA_{r,i,(t-1)}}{\gamma_i * CPCI_{r,i,(t-1)} + (1-\gamma_i) * CPCI_{r,i,t}}\right)$$

$$+ \beta_{2,r,c}.\text{trend} + log\left(R_{r,c,t}\right) \qquad (1)$$

where

r = Brazil

c = *i* = cotton, maize, rice, roots and tubers, soybeans, sugar cane, wheat

t = year

Here the area harvested is a function of a constant (α), last year's harvested area $(AH_{r,c,(t-1)})$, plus the sum of the own and cross land supply elasticities $(\beta_{r,c,i})$ multiplied by last year's return per hectare $(RH_{r,i,(t-1)})$ plus effective area payments $(EPA_{r,i,(t-1)})$ divided by this year’s and last year's commodity production cost indices $(CPCI)$ multiplied by the share of production cost occurring in the previous marketing year (γ_i), plus a time *trend* and a calibration parameter (*R*).

([3]) The own land supply elasticity is the land competition component of the area elasticity of crop *c* with respect to its own return. The cross-land supply elasticity is the land competition component of the area elasticity of crop *c* with respect to the return of crop *i*.

In some countries where a second or third crop is common, using equation (1) could be difficult, especially if the second crop's grown area exceeds the first crop’s harvested area. In addition, the incentives (i.e. change in expected returns) to plant a first and a second crop (e.g. beans) could vary, resulting in different areas harvested from estimated by equation (1). Moreover, second crops compete for land among fewer potential crops that can be sown.

In Brazil the second crop (or multiple crops) has an important role in agricultural production. In 2015 around 65 % of maize and bean production stemmed from the second crop, or multiple crops in the case of beans (CONAB, 2017). As a matter of fact, wheat is produced only as a second crop. Clearly, agricultural land use in Brazil differs significantly from other countries because of the multi-cropping component of the agricultural system. Therefore, modelling only harvested area is not enough.

The methodology proposed to remedy these short comings in the Brazilian land use module is explained below. Here the distinction is made between first and second crops’ harvested areas with a two-tier nested system that replaces equation (1) above. In the top tier we redefine equation (1) to represent actual land use ($LU_{r,c,t}$) in Brazil (*r*) for the first crop sown (*c*) in year *t.*

$$\log\left(LU_{r,c,t}\right) = \alpha_{r,c} + \sum_{i=1}^{7} \beta_{1,r,c,i} . \log\left(\frac{RH_{r,i,(t-1)} + EPA_{r,i,(t-1)}}{CPCI_{r,i,(t-1)}}\right) + \log\left(R_{r,c,t}\right) \qquad (2)$$

where

r = Brazil

c = *i* = beans first crop, cotton, maize first crop, beef cattle pasture, rice, soybeans, sugar cane

t = year

Equation (2) is a simplified version of equation (1), covering a different range of crops. It no longer covers wheat or roots and tubers, while beans first crop and beef cattle pasture land have been added. Maize is adjusted to represent the first crop grown. By adding pasture land used by beef cattle to the land use equation, the returns per hectare (RH) of pasture land are then linked to the beef producer price ($PP_{r,BV,t}/LU_{r,BV,t}$) and the commodity production cost indices ($CPCI$) of meat and dairy.

The calibration of equation (2) for the seven agricultural activities mentioned (i.e. six crops plus pasture) falls in line with the work undertaken by the Instituto de Estudos do Comércio e Negociações Internacionais (ICONE), which is used to estimate the own and cross land supply elasticities ($\beta_{1,r,c,i}$). Whereas equation (1) covered an area of 65 million hectares, of which 11 million were second crops, the new land use equation (2) includes 206 million hectares (first crop), of which pasture accounts for 151 million hectares in 2015. Equation (3) allocates land to the second crops, covering about 13 million hectares in 2015.

$$\log\left(AH\_2nd_{r,c,t}\right) = \alpha_{r,c} + \sum_{i=1}^{3} \beta_{2,r,c,i} . \log\left(\frac{RH_{r,i,(t-1)} + EPA_{r,i,(t-1)}}{CPCI_{r,i,(t-1)}}\right) + \log\left(R_{r,c,t}\right) \qquad (3)$$

where

r = Brazil

c = *i* =beans second crop, maize second crop, wheat second crop

t = year

Here the three crops, beans, maize and wheat, that are typically sown as second crops compete for land through the own and cross land supply elasticity $\beta_{2,r,c,i}$ as the relative changes in expected returns from year to year.

The total area harvested ($AH_{r,c,t}$) is then simply calculated as:

$$AH_{r,c,t} = LU_{r,c,t} + AH\_2nd_{r,c,t} \tag{4}$$

where

r = Brazil

c = beans, cotton, maize, beef cattle pasture, rice, soybeans, sugar cane, wheat

t = year

and a multiple-cropping index $CRPI_{r,c,t}$ is calculated residually.

$$CRPI_{r,c,t} = \frac{LU_{r,c,t}}{AH_{r,c,t}} \tag{5}$$

By construction, this index will have values varying between 0 (no first crop) and 1 (no second crop). The exception to this would be sugar cane production, because of the lag between plantation and first harvest. Since it takes about 18 months between those two moments, land use is typically larger than area harvested and for that reason the index could be above 1.

2.3 Update of elasticities

As mentioned above, ICONE generated land allocation elasticities for its Brazilian Land Use Model (BLUM) (ICONE, 2016). It considered pasture and beans and their interaction with the other commodities included in Aglink-Cosimo. For both beans and maize, the matrix of elasticities is calculated only for the first crop, which is exactly what is needed to have a clear distinction in the model between the first and second crops and, hence, calculate the actual land used (LU). Since wheat is solely produced as a second crop, it does not appear in the BLUM matrix of elasticities. Other minor crops, and roots and tubers, are not included. Considering the extensive work done by ICONE and its complexity, these regional elasticities are used to estimate the own and cross land supply elasticities $\beta_{1,r,c,i}$ utilised in equation (2).

The initial BLUM is composed of six regions for which individual matrices of competition and scale land supply elasticities have been estimated for seven activities: sugar cane, soybeans, rice, cotton, maize (first crop), beans (first crop) and pasture. Since Aglink-Cosimo is not regional, weighted averages were calculated using BLUM regional elasticities and planted area data from IBGE (2017). Combining the weighted average scale effect and competition land supply elasticities, a matrix of first crop land supply elasticities was calculated (see Table 2).

Table 2. Matrix of first crop land supply elasticities

$(\boldsymbol{\beta}_{1,r,c,i})$	**Soybeans**	**Maize first crop**	**Cotton**	**Rice**	**Beans first crop**	**Sugar cane**	**Pasture**
Soybeans	**0.453**	−0.2500	−0.0874	−0.0418	−0.0324	−0.0168	−0.0918
Maize	−0.0416	**0.1955**	−0.0208	−0.0093	−0.0118	−0.0087	−0.0071
Cotton	−0.0070	−0.0290	**0.2385**	−0.0002	−0.0003	−0.0017	−0.0007
Rice	−0.0109	−0.0109	−0.0019	**0.1429**	−0.0119	−0.0036	−0.0033
Beans	−0.0027	−0.0130	−0.0007	−0.0012	**0.0980**	−0.0001	−0.0030
Sugar cane	−0.0837	−0.1563	−0.0195	−0.0126	−0.0048	**0.4004**	−0.0250
Pasture	−0.0334	−0.0202	−0.0102	−0.0075	−0.0042	−0.0046	**0.1021**

Source: own estimation based on the BLUM elasticities (Harfuch *et al.*, 2011).

Competition for the second use of land also takes place between maize, wheat and beans. For instance, 97 % of wheat production is grown in the south, competing for the second use of land with beans and maize. Since beans are more a staple food and generally cultivated on small farms, a small amount of elasticity would be expected. Regarding wheat and maize, it is clear that from the fluctuation over time the second crop land supply elasticity should be stronger than for the first crop. However, since the amount of land available for the second crop is very large, imposing homogeneity of degree 0 would be a problem because we would neglect an important scale effect (4).

The own and cross land supply elasticities $(\beta_{2,r,c,i})$ for the second crop were estimated using the Aglink-Cosimo historical database (i.e. 1997 to 2014). Initially, Zellner's seemingly unrelated method (5) was used to estimate a matrix of elasticities for the second crop (i.e. maize, wheat and beans) where symmetry was imposed. However, results were not satisfactory because of a strong complementarity effect between wheat and maize resulting from highly correlated returns per hectare between these two crops. The problem was solved by aggregating wheat and maize into one crop aggregate (6). With this specification the results were statistically significant and respected our a priori expectation of a low own land supply elasticity for beans and a higher one for the wheat and maize aggregate.

The next step consisted of disaggregating wheat and maize by using an ordinary least squares estimation. Wheat and maize crop shares were estimated as a function of the ratio of the returns per hectare between the two crops. The returns per hectare were calculated using the Aglink-Cosimo general specification (see Enciso *et al.*, 2015) divided by the cost of production index.

The resulting parameters were significant and had the right sign. Since the explanatory variable considered was the ratio of returns, the cross land supply elasticities were negative by construction. After some mathematical manipulations (i.e. the estimation was done with shares) and ensuring symmetry, the following matrix of elasticities was generated (Table 3).

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(4) The competition effect is the allocation of a fixed amount of land between all agricultural commodities. If all returns increase by 1 % there is no change in land use (i.e. the system is homogeneous of degree 0). The scale effect allows for an increase in total land use due to the elasticities used in the equations. In this case the system is not homogeneous of degree 0.

(5) Zellner's method takes into account the correlation of the error terms of the different equations appearing in the system. In this case it is applied to the estimation of the land supply elasticities.

(6) In the presence of highly correlated explanatory variables the first and easiest solution is to merge the two series into one variable.

Table 3. Matrix of land supply elasticities of the second crop area harvested

$(\beta_{2,r,c,i})$	**Wheat**	**Maize**	**Beans**
Wheat	2.41	−0.89	−0.15
Maize	−0.182	1.70	−0.15
Beans	−0.178	−0.63	0.176

Source: own estimation.

As mentioned above, homogeneity of degree 0 was not imposed on the estimation of second crop elasticities. Therefore, the total weighted average reaction (i.e. the scale effect) when all prices increase by 1 % is an increase in the second crop harvested area of 1.14 % (7). This high value is not surprising considering the strong growth observed in the second crop of maize in the last few years (Figure 2).

2.4 Updating the cost of production share of five inputs

Every year the Companhia Nacional de Abastecimento (CONAB) publishes estimates of the cost of production of all the commodities covered in this report. The disaggregation provided is sufficient to split the information according to the five input categories included in Aglink-Cosimo, namely energy, fertiliser, seed, other tradables and non-tradables. For the update of the commodity production cost indices in Aglink-Cosimo, the latest estimates were used: 2015 for wheat, 2013/2014 for sugar cane and 2014/2015 for cotton, rice, soybeans, maize and beans. A national average was obtained by the regional production cost weighted by the production. With this information, all area and yield equations in Aglink-Cosimo were re-estimated.

2.5 Pasture area

Land used for pasture is an integral part of the supply function of ruminant production. Since pasture area has been incorporated in the land allocation system in equation (2), it already captures elements of the ruminant production supply function. For that reason this part of the supply function cannot be used again in determining the beef cow supply function (8).

Beef cattle constitute by far the largest ruminant production system in Brazil but since milk production is not insignificant it was also considered in the land allocation. We initially split the total pasture land data in the database between beef and milk cattle on the basis of their proportions of the inventory of cattle:

$$LU_{r,BV,t} = LU_{r,PA,t}\cdot\left[\frac{LI_{r,BV..oth,t} + CI_{r,BV,t}}{LI_{r,BV,t}}\right] \tag{6}$$

$$LU_{r,MK,t} = LU_{r,PA,t}\cdot - LU_{r,BV,t}\cdot$$

$$LI_{r,BV,t} = LI_{r,BV..oth,t}\cdot + CI_{r,BV,t}\cdot + CI_{r,MK,t}\cdot$$

where *LU* denotes land use, *LI* livestock inventory, *CI* cow inventory, *BV* beef and veal cattle, including calves but excluding cows, *MK* milk, *PA* total pasture land, *r* Brazil and *t* the year.

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(7) The area harvested of Table 1 and the sum of the elasticities of Table 3 were used.

(8) This would expose the model to a rank-deficient matrix, i.e. two or more equations not being linearly independent.

We used the amount of pasture land for beef cattle in the land allocation system (equation (2)) while the amount of land for dairy cattle is directly modelled as a function of the milk cow inventory supply function already appearing in Aglink-Cosimo.

$$\log\left(LU_{r,MK,t}\right) = \alpha_{r,MK} + \beta_{r,MK}.\log\left(CI_{r,MK,t}\right) + \beta_{r,MK}.\text{trend} + \log\left(R_{r,MK,t}\right) \tag{7}$$

Pasture area for beef production is mainly driven by the returns per hectare ($RH_{r,BV,t}$) from beef production in real terms, which is calculated just like the crops return per hectare (see Enciso *et al.*, 2015) divided by the meat and dairy price deflator index. Total pasture land is the sum of the amount used for beef and for dairy cattle.

$$LU_{r,PA,t} = LU_{r,BV,t} + LU_{r,MK,t} \tag{8}$$

Having elements of the supply function of beef production in the land allocation system forces changes to the beef cow inventory supply function in the model. The elements already appearing in the land allocation system were taken out of the beef cow inventory function and only the elements capturing the level of intensity were kept. This beef cow intensity function (i.e. inventory divided by land use) was estimated econometrically (ordinary least squares) with data from 1996 to 2014 and with three explanatory variables: time trend, price of beef in real terms and the lagged endogenous variable.

$$\log\left(\frac{CI_{r,BV,t}}{LU_{r,BV,t}}\right) = \alpha_{r,BV} + \beta_{1,r,BV}.\log\left(\frac{CI_{r,BV,t-1}}{LU_{r,BV,t-1}}\right) + \beta_{2,r,BV}.\log\left(\frac{PP_{r,BV,t-1} + EPQ_{r,BV,t-1}}{CPCI_{r,MD,t-1}}\right) + \beta_{3,r,BV}.\text{trend} + \log\left(R_{r,BV,t}\right) \tag{9}$$

The resulting short-term elasticity is 0.07 and the long-term elasticity is 0.26 ([9]). Note that in this new version of the model all crop prices will influence the beef cow inventory through changes in the amount of land used for pasture because of the cross land supply elasticities in equation (2) above.

2.6 Beans

Only the supply side of the bean market in Brazil was included in the model. As indicated above, beans are part of the first and second crop land allocation system and, since yield is sufficiently different between the two harvests, equations for yields (equations 10, 11 and 12) and return per hectare (*RH*) are added to the model for both harvests.

$$\log\left(YLD_{c,r,t}\right) = \alpha_{c,r,t} + \xi_{YLD,PP}.\log\left(\frac{PP_{c,r,t} + EPY_{c,r,t}}{CPCI_{c,r,t}}\right) + \beta_{c,r,t}\text{trend} + log(R_{c,r,t}) \tag{10}$$

$$YLD1\text{st}_{c,r,t} = (\alpha1\text{st}_{c,r,t} + \beta1\text{st}_{c,r,t}(YLD_{c,r,t}))R1\text{st}_{c,r,t} \tag{11}$$

$$YLD2\text{nd}_{c,r,t} = (\alpha2\text{nd}_{c,r,t} + \beta2\text{nd}_{c,r,t}(YLD_{c,r,t}))R2\text{nd}_{c,r,t} \tag{12}$$

where

([9]) Since the equation is in logarithms, the econometric estimation of β_2 generates the short-term elasticity directly. The long-term elasticity is calculated in the following way: $\beta_2/(1 - \beta_1)$.

c = beans

r = Brazil

t = year

$YLD_{c,r,t}$ denotes the average yield of beans, $\alpha_{c,r,t}$ is a constant, $\xi_{YLD,PP}$ is the yield to price elasticity, $PP_{c,r,t}$ is the price of beans in region r in year t, $EPY_{c,r,t}$ is any support payments given to farmers, $CPCI_{c,r,t}$ is the cost of production index for beans, trend is a time trend and $R_{c,r,t}$ is a calibration parameter. The average yield of beans is then linked to the specific yields of the first and second crops (^{10}) by estimating the coefficients α and β in equations (11) and (12), where R is a calibration parameter.

Crop returns are calculated as a 3-year weighted average, to remove the effect of the strong variability in yields and prices, as follows:

$$RH_{c,r,t} = 0.5PP_{c,r,t}.YLD_{c,r,t} + 0.3PP_{c,r,t-1}.YLD_{c,r,t-1} + 0.2PP_{c,r,t-2.}YLD_{c,r,t-2} \qquad (13)$$

where

c = beans first and second crops

r = Brazil

t = year

where $PP_{c,r,t}$ is the producer price of beans in Brazil, in year t, and $YLD_{c,r,t}$ is the yield of beans in the first and second crops.

Since the demand side of beans is still not fully covered in Aglink-Cosimo, no linkages with world markets are considered.

2.7 Internal transport cost

The Sistema de Informações de Fretes (SIFRECA) of São Paulo University in Brazil publishes transport cost data from different inland locations and different ports for different commodities. Here it becomes apparent that wheat and sugar cane are grown almost entirely in regions close to the ports and are, therefore, only marginally affected by internal transport costs. However, cotton is the commodity most severely affected, since 96 % of the area planted is in the inland regions of Northern Amazonia, Centre-West Cerrado and Northeast Cerrado (^{11}). Rice, maize and soybeans are also grown in these three inland regions, but a large share of production is also grown in regions closer to the ports. Over time it seems that rice production is moving closer to the ports, while maize and soybean production is moving in the opposite direction: inland (see Figures 3 and 4 above).

The most complete and the longest historical data series on transport costs published by SIFRECA are for soybeans between the state of Mato Grosso and the port of Santos. This data series is therefore used to estimate internal transport cost for the four inland commodities cotton, rice, maize and soybeans, while at the same time exogenous

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(^{10}) For beans the second crop represents both the second and third crops.

(^{11}) These regions were chosen according to the definition adopted by ICONE in the BLUM model. The South region covers the states of Paraná, Santa Catarina and Rio Grande do Sul; Southeast the states of São Paulo, Rio de Janeiro, Espírito Santo and Minas Gerais; Centre-West Cerrado the states of Mato Grosso do Sul and Goiás and part of the state of Mato Grosso inside the biomes Cerrado and Pantanal; Northern Amazon part of the state of Mato Grosso inside the Amazon biome, and the states of Amazonas, Pará, Acre, Amapá, Rondônia and Roraima; Northeast Coast the states of Alagoas, Ceará, Paraíba, Pernambuco, Rio Grande do Norte and Sergipe; and Northeast Cerrado the states Maranhão, Piauí, Tocantins and Bahia.

variables are incorporated in the model to capture changes in the geographic distribution of production.

In Aglink-Cosimo, prices are transmitted through import and export functions in which the domestic price is divided by a reference world price. In large countries such as Canada, USA, Russia and Brazil, internal transport costs can be large relative to the price received by farmers. On that basis, it is better, if possible, to introduce the internal transport cost in these functions.

In the case of Brazil, transport costs are introduced as a discount to the export price in the export function (equation 14), fully in the case of cotton, since almost all production is far from the ports, and partially (but changing over time) in the case of soybeans, maize and rice.

$$\log(EX_{c,r,t}) = \alpha_{c,r,t} + \xi_{EX_c,PP_c}.\log\left(\frac{PP_{c,r,t}}{\left(EXP_{c,r,t} - AH\_FAR_{c,r,t}.TC_t\right)\left(1 + TAVE_{c,r,t}/100\right)}\right) + \log(R_{c,r,t}) \quad (14)$$

r = Brazil

c = cotton, soybeans, maize and rice

t = year

where $EX_{c,r,t}$ is the export quantity (tonnes), ξ_{EX_c,PP_c} is the price elasticity of exports, $PP_{c,r,t}$ the producer price of commodity *c* in region *r* in year *t*, $EXP_{c,r,t}$ is the export price, $AH\_FAR_{c,r,t}$ is the share of the commodity *c* harvested far from the ports ([12]), TC_t is the transport cost of soybeans between the state of Mato Grosso and the port of Santos, $TAVE_{c,r,t}$ is the ad valorem export tariff for commodity *c* in region *r* in year *t* and $R_{c,r,t}$ is a calibration parameter.

Since 97 % of the wheat area harvested is found in regions considered to be close to ports, no reduction in wheat transport costs was modelled. Likewise for sugar cane, most of which is also produced in regions close to the ports.

([12]) By convention we have classified the production in Centre-West Cerrado and Northern Amazon as being far from the port.

3 New baseline and illustrative scenarios

For the analysis a new baseline scenario is constructed, based on the EU Outlook 2016-2026 (EC, 2016) and including the newly developed land use module for Brazil. This baseline should serve as a reference point for testing the economic impacts of alternative policy scenarios. Regarding Brazilian land use and livestock stocking density, Table 4 gives an overview of the main variables comprised in this new baseline.

Table 4. Brazilian land use and herd size, baseline, 2006-2026

Variable	**2006**	*% Change* 2006-2016	**2016**	*Change 2016-2026*	**2026**
Crops (million ha)					
Total area harvested	229.7	*9.0*	238.7	*–3.7*	235.1
Second crop	6.6	*5.5*	12.1	*1.2*	13.3
First crop land use (incl. pasture)	223.1	*3.5*	226.6	*–4.9*	221.8
of which					
- Pasture land	175.5	*–6.9*	168.7	*–14.8*	153.9
- Crop land	47.6	*10.4*	58.0	*9.9*	67.9
Cattle					
Herd (million heads)	205.9	*18.4*	224.3	*19.5*	243.8
Head/hectare	1.17	-	1.33	-	1.59

Source: own calculations, Aglink-Cosimo model, December 2016.

Compared with the historical data depicted in Figures 1 and 3, the baseline follows the same trend in the period 2006 to 2016. Both the first and second crop land uses are expanding, with pasture land declining. The herd size is increasing, raising the livestock stocking density (i.e. head/hectare) to 1.33 in 2016. The baseline then moves forward, taking global supply and demand for agricultural markets to 2026. Here it is envisaged that pasture land in Brazil will decline even further, with herd sizes increasing and the livestock stocking density reaching 1.59. At the same time, the first crop land use area (excluding pasture) is expected to expand by 9.9 million hectares.

Against this baseline scenario, three illustrative counterfactual scenarios are tested here with a focus on the Brazilian land use dynamics (Table 5).

Table 5. Illustrative scenarios for testing the Brazilian land use module

Scenario	**Short description**
1: Elimination of the Brazilian biofuel blending mandates	This scenario simulates the abolishment of the biofuel blending mandates imposed in Brazil. Here the volumetric blending rates for anhydrous ethanol (27 %) and biodiesel (7 %) are removed in order to gauge its impact on land use in Brazil
2: Scenario 1 plus improved cattle production intensity	Biofuel blending mandates are eliminated and at the same time livestock density per hectare is improved, so that total land use area remains unchanged
3: Reduction in transport costs to improve agricultural trade	Transport costs between the state of Mato Grosso (inland) and the port of Santos are reduced by 50 % over the first 5 years of the baseline

Scenario 1: Abolishing Brazilian biofuel blending mandates

The elimination of the biofuel blending mandates in Brazil is expected to have a significant impact on soybean and sugar cane production, as these are used as feedstock in biodiesel and ethanol respectively. In the case of soybeans, how these policy changes translate into the farmers' planting decisions in Brazil is complex. The impact on production comes from the market reactions highlighted in Table 6.

Table 6. Abolition of biofuel mandates in Brazil, 2026

Variables	**Ethanol**			**Biodiesel**		
	Baseline 2026	*% change*	Scenario 1 2026	Baseline 2026	*% change*	Scenario 1 2026
Millions of litres						
Production	36 040	*–16*	30 448	4 305	*–7*	3 997
Reduction in inventory	228	*–2*	223	19	*–100*	0
Domestic consumption	34 971	*–23*	26 935	4 282	*–100*	0
Export	1 297	*188*	3 736	42	*9417*	3 997
	Sugar					
Production (*thousand tonnes*)	42 538	*8*	46 078			
	Sugar cane			Soybeans		
Production (*thousand tonnes*)	805 080	*–4.7*	767 246	140 668	*0.2*	140 943
Area harvested (*million ha*)	11.5	*–3.8*	11.0	42.3	*0.2*	42.4
Million ha	Total agricultural area					
Total area harvested	235.1	–0.16	234.7			
Total land use	221.8	–0.14	221.5			
Second crop area	13.3	–0.47	13.2			

Source: own estimation, Aglink-Cosimo model, December 2016.

In a nutshell, the abolition of the blending mandates reduces the price of biodiesel by 8 % and changes the consumption pattern in Brazil drastically. Biodiesel is no longer consumed in the domestic market but is solely exported to the rest of the world. Moreover, the elimination of the blending mandate in Brazil reduces the world price of biodiesel and facilitates the achievement of biofuel consumption mandates in many other countries around the world. As a result, the world production declines by 774 million litres. A large share of this drop in production will not come from soybean-oil-based biodiesel. Consequently, the price impact of the abolition of the mandate on the world soybean oil market is diluted as oil production from other crops adjusts.

Many other factors affect soybean farm gate prices in Brazil. First, a decrease in soybean oil based biodiesel production generates a lower demand and price for soybean oil. However, since the price of soybean oil in Brazil is strongly determined by the much larger world market, the effect on the Brazilian/world market price of abolishing the blending mandate is marginal. The world soybean oil market is in fact part of an even larger vegetable oil market, which also contributes to minimise the impact on soybean prices in Brazil.

Furthermore, a decrease in world vegetable oil prices resulting from the elimination of this policy (even if small) will generate a smaller demand for crushing, which will produce less oil but also less meal, since these commodities are joint products. This will increase the world price of meals. Since soybeans have the highest yield of meal and the lowest yield of oil, the demand for soybeans will not decrease as much as the demand for sunflower or rapeseed. In the end, the world price of soybeans will decrease only marginally because the price of meal will increase when mandates are abolished. Since the Brazilian price of soybeans is also strongly determined by the world export market, abolishing the mandates will reduce soybean prices in Brazil by only 0.4 % in 2026.

Turning to the ethanol market, the elimination of the anhydrous blending mandate will reduce the ethanol producer price by 20 % in Brazil by 2026. This will automatically increase ethanol consumption by 22 %, possible because of the large flex-fuel car fleet in Brazil, and will boost Brazilian exports of ethanol by almost 190 %. This increased demand (flex-fuel cars and exports) will reduce the impact of abolishing the blending mandate, so ethanol production will decline by only 16 % in 2026.

In Brazil, most ethanol plants can switch production to a certain degree from ethanol to sugar production. Therefore, the decline in the ethanol price caused by eliminating the blending mandate will generate a switch from ethanol to sugar production, which will increase by 8 %. Since Brazil is a large player on the world sugar market, its increased production will probably reduce domestic and world sugar prices. The decline in the Brazilian sugar price (−3 % in 2026) is much smaller than the decline in the ethanol price (−20 %), resulting in a 10 % reduction in the sugar cane price received by farmers.

The analysis shows that the two incentive prices for farmers’ planting decisions will drop by 0.4 % for soybeans and by 10.3 % for sugar cane. Since these commodities are an integral part of the land allocation system in Brazil, a decline in their prices will automatically generate a shift in farmers’ planting decisions. The harvested area of sugar cane is expected to decline by 3.8 %, while the soybean area will increase slightly (0.2 %) because the reduction in the price of sugar cane will be larger (13).

Given all of these market effects, it is clear that the elimination of the biofuel blending mandates in Brazil in 2018 will have a very small impact on total land use in Brazil. According to the Aglink-Cosimo model, the biofuel mandates in Brazil are responsible for expanding the agricultural harvested area in Brazil by only 0.4 million hectares. The impact would have been much stronger if the scenario had been simulated starting in the year of the introduction of the mandates (14).

This might seem surprisingly insignificant, but this scenario shows the importance of having a complete model such as Aglink-Cosimo to analyse indirect land use changes (ILUC) given the numerous linkages that a market economy always encompasses.

Scenario 2: Changing livestock density

The small difference in land use between the baseline and the results of the abolition of the blending mandates can be reduced to zero by simply adjusting the grazing intensity of beef cattle. This can be represented in the model by two alternative options: (a) by changing pasture quality to reduce the stocking density per hectare (which Aglink-Cosimo cannot capture but can be imposed indirectly) or (b) by reducing the amount of concentrated feeds going into beef cattle. With the first option, the stocking density per hectare would have to decline by only 0.14 % in 2026 to expand pastureland by 0.4 million hectares. The reverse argument is that it would require an increase in the stocking density for beef production of only 0.14 % to avoid any land use changes due to the presence of blending mandates in Brazil. With the second option, the quality of pasture land is maintained, but the amount of concentrated feed used for beef cattle

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(13) The harvested area of soybeans is affected by the larger price reduction in sugar cane through the cross price elasticities (see Table 3), so that land moves into soybean production.

(14) In 2005 in the case of biodiesel and in 1975 in the case of ethanol (Programa Nacional do Álcool).

production is reduced, thereby increasing the required amount of pasture land (15). In this scenario it was calculated that 0.2 million tons of concentrated feed had to be removed to maintain the agricultural area unchanged. In both cases it is clear that the cattle sector could easily adjust to prevent any changes in land used due to the biofuel blending mandates in Brazil.

Scenario 3: Declining transport cost

The third scenario consists of a gradual decline in internal transport cost over the first five years of the outlook period, to eventually reach (and maintain) a 50 % reduction.

The impact of the reduced transport costs depends on the share of production located in inland regions far away from the ports and the unit price of each product. On the one hand, a product with a high unit value (per tonne), such as cotton, will be less affected by the transport cost, even though most of its production lies in inland regions. On the other hand, a product such as maize, with a low unit value compared with other crops, will experience a stronger impact.

Since the cost of transporting crops produced inland to the main harbours declines, the initial export price will also decline, increasing Brazil's competiveness on the world markets. Compared with the baseline, maize exports will increase by 38 % or 12 million tonnes (mt) in 2026, while soybean and rice exports will increase by 4.7 % (3.3 mt) and 15 % (0.17 mt) respectively. This increased export demand will push up the domestic farm gate prices. As expected, the largest impact will be on the domestic maize price, with a 6.2 % increase, followed by soybeans, cotton and rice with 3.0 %, 1.3 % and 1.0 % increases respectively.

The negative impact of these price increases will be absorbed by the domestic market, where the increase of the maize price is expected to generate a 2.3 % increase in the feeding costs of non-ruminants. This will lead to declines in production of eggs, poultry and pork by 0.3 %, 3.0 % and 1.6 % respectively, with domestic prices increasing.

Eggs are a non-tradable product in Aglink-Cosimo, so the domestic price will follow the change in feed costs more closely (1.9 % in 2026). At the same time, pork and poultry prices will increase by only 0.4 % and 0.5 % respectively, since they are more heavily traded and cannot detach themselves from their respective international prices. Given the increases in the Brazilian prices of maize, soybeans, cotton and rice, the crop area harvested in Brazil will expand in scenario 3 by about 0.8 million hectares (Table 7).

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(15) The following assumptions were made when the required adjustment to cattle concentrates within Aglink-Cosimo were calculated. According to César (2006), at the beginning of the century the yield of dry matter per hectare on natural pasture in Southern Brazil varied between 2.5 and 4.0 tonnes per year. In this scenario, considering the share of improved pasture and the geographical distribution of pasture in Brazil, it was assumed that the average yield for the country as a whole over the outlook period is 3 tonnes per hectare. That assumption gave reasonable results since the proportion of concentrated feeds consumed by ruminants is 7 % on a volumetric basis according to the Aglink-Cosimo calculations. Following Rasby (2012), a ration containing 30 % of concentrated feeds and 70% of hay could replace one to one a feed ration based on pasture. Given these and the known reduction in stocking density per hectare obtained from the first option it was possible to calculate the necessary reduction in concentrated feeds consumed to keep the agricultural area unchanged.

Table 7. Reductions in transport costs and Brazilian land use, 2026

Variables	Baseline 2026	*Change*	Scenario reduced transport cost 2026
Crops (million ha)			
Total area harvested	235.1	*0.8*	236.0
Second crop	13.3	*1.5*	14.8
First crop land use (incl. pasture)	221.8	*–0.7*	221.1
of which			
- Pasture land	153.9	*–0.6*	153.3
- Crop land	67.9	*–0.1*	67.8
Cattle			
Herd (million head)	243.8	*–0.8*	243.0
Head/hectare	1.59	*0.001*	1.59

Source: own estimation, Aglink-Cosimo model, December 2016.

The reduction in transport cost will expand the production of the second crop in 2026 by 1.5 million hectares, with a large increase in maize production. This is not surprising given the large expansive elasticities used in the model (Table 3). The increased feed costs will also reduce the relative returns per hectare of pasture land, which, combined with the increased return per hectare of maize, soybeans, cotton and rice, will reduce both the bovine herd size and the pasture area in Brazil.

4 Conclusions

This project has allowed a great improvement of the Brazilian component of the Aglink-Cosimo model. First, the area allocation system has been split into two components: first crop and multiple cropping, and elasticities re-estimated using the work done by ICONE on the BLUM model and own estimations. Second, the pasture and beans sectors have been added to the model. Third, the cost of production indices used in the model have been updated to reflect the cost structure in 2013-2014 or 2014-2015. Last but not least, internal transport costs have been added to the export function of cotton, soybeans, maize and rice.

To verify the behaviour of the model, three scenarios have been included. The first concerns the elimination of the two blending mandates in Brazil for anhydrous ethanol and biodiesel, with the objective of discovering the impact of these policies on the total amount of land used in Brazil. The main conclusion that can be drawn from this scenario, using the revised model, is that, *the more open an economy is, the smaller is the impact of its own policies on domestic land used*. The link between domestic policies and land used in Brazil is extremely weak because of the country's strong link to the world market.

A second scenario estimated how much the beef cattle stocking density had to change to prevent additional land use due to the biofuel blending mandates. Given the results of the first scenario, it is clear that only small adjustments were needed. Two different alternatives were analysed: (a) a change in the quality of pasture and (b) a lower amount of concentrated feeds given to beef cattle production. In both cases the impacts on the markets were relatively small.

A third scenario was produced to verify the property of the price transmission of the model with the addition of internal transport costs. The main conclusion is that the key driver of the Brazilian domestic price of maize, soybeans, cotton and rice remains the world price, but that internal transport costs are not insignificant, especially for maize. As expected, a decline in internal transport costs generates a large increase in exports

The scenarios demonstrated the importance of having a complete model such as Aglink-Cosimo to analyse direct and indirect land use changes. The scenarios also showed that the land use response in Brazil is strongly linked to the world market, so updating the Brazilian module is also an important contribution to evaluating the impact of policy change in other countries as well as within Brazil, when prices change.

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Annex Brazilian Land use driver (PC-Troll)

Note: Note: this model driver is designed such as to work following the tree-filing structure used by the Aglink team at the JRC. It should provide the reader with the relevant equations and an idea of how this exercise has been conceptualized. Naturally, any Aglink-Cosimo user should be able to replicate it. Any missing information (e.g. specific data files) can be freely provided by the authors of this report upon request.

```
//================================================================================================
// Name: BRAZILLANDUSEDRIV - driver for analysing land use elements in Brazil
// Called by:
// Last modified: November 2016
// Structure:
// PART 1: model modifications
// PART 2: imposition estimation of coefficients
// PART 3: calibration and testing for reproduction of the Baseline
//
// Author: Pierre Charlebois, Ignacio Pérez Domínguez and Silvia Kanadani Campos
//================================================================================================

//================================================================================================
// SET ENVIRONMENT SETTING:
//================================================================================================
DELACCESS all;DELSEARCH all;DELSAVE all;
ACCESS OECDLIB TYPE DISK ID ".\\..\\Macros" MODE R ; SEARCH LAST PROGRAM OECDLIB;

//================================================================================================
// PART 1: INTRODUCE ALL THE MODIFICATION RESULTING FROM THE REVISION OF THE BRAZILIAN COMPONENTS
// WITHOUT FILING THEM
//================================================================================================

DELACCESS all;DELSEARCH all;DELSAVE all;

USEMOD; USEMOD ._.._ModelTags_EC2016_aglinkeu;

// THESE COMMANDS
ADDEQ BOTTOM,

// LAND USE, SLIGHTLY LONGER LAG IS USED FOR SCA TO REFLECT ITS PERENNIAL NATURE

BRA_MA_LU: LOG(BRA_MA_LU'N) = C.BRA_MA_LU.CON'C
                      +C.BRA_MA_LU.BRA_SB_RH'P*LOG((BRA_SB_RH(-1)+BRA_SB_EPA(-1))/BRA_SB_CPCI(-1))
                      +C.BRA_MA_LU.BRA_MA_RH'P*LOG((BRA_MA_RH(-1)+BRA_MA_EPA(-1))/BRA_MA_CPCI(-1))
                      +C.BRA_MA_LU.BRA_CT_RH'P*LOG((BRA_CT_RH(-1)+BRA_CT_EPA(-1))/BRA_CT_CPCI(-1))
                      +C.BRA_MA_LU.BRA_BN_RH'P*LOG((BRA_BN_RH..1ST(-1)+BRA_BN_EPA(-1))/BRA_BN_CPCI(-1))
                      +C.BRA_MA_LU.BRA_RI_RH'P*LOG((BRA_RI_RH(-1)+BRA_RI_EPA(-1))/BRA_RI_CPCI(-1))
                      +C.BRA_MA_LU.BRA_SCA_RH'P*LOG((BRA_SCA_RH(-1)
                      +BRA_SCA_EPA(-1))/BRA_SCA_CPCI(-1)+(BRA_SCA_RH(-2)+BRA_SCA_EPA(-2))/BRA_SCA_CPCI(-2))
                      +C.BRA_MA_LU.BRA_BV_RH'P*LOG((BRA_BV_RH(-1)+BRA_BV_EPQ(-1))/BRA_MD_CPCI(-1))
                      +LOG(R.BRA_MA_LU'POL),

BRA_SB_LU: LOG(BRA_SB_LU'N) = C.BRA_SB_LU.CON'C
                      +C.BRA_SB_LU.BRA_SB_RH'P*LOG((BRA_SB_RH(-1)+BRA_SB_EPA(-1))/BRA_SB_CPCI(-1))
                      +C.BRA_SB_LU.BRA_MA_RH'P*LOG((BRA_MA_RH(-1)+BRA_MA_EPA(-1))/BRA_MA_CPCI(-1))
                      +C.BRA_SB_LU.BRA_CT_RH'P*LOG((BRA_CT_RH(-1)+BRA_CT_EPA(-1))/BRA_CT_CPCI(-1))
                      +C.BRA_SB_LU.BRA_BN_RH'P*LOG((BRA_BN_RH..1ST(-1)+BRA_BN_EPA(-1))/BRA_BN_CPCI(-1))
                      +C.BRA_SB_LU.BRA_RI_RH'P*LOG((BRA_RI_RH(-1)+BRA_RI_EPA(-1))/BRA_RI_CPCI(-1))
                      +C.BRA_SB_LU.BRA_SCA_RH'P*LOG((BRA_SCA_RH(-1)
                      +BRA_SCA_EPA(-1))/BRA_SCA_CPCI(-1)+(BRA_SCA_RH(-2)+BRA_SCA_EPA(-2))/BRA_SCA_CPCI(-2))
                      +C.BRA_SB_LU.BRA_BV_RH'P*LOG((BRA_BV_RH(-1)+BRA_BV_EPQ(-1))/BRA_MD_CPCI(-1))
                      +LOG(R.BRA_SB_LU'POL),

BRA_CT_LU: LOG(BRA_CT_LU'N) = C.BRA_CT_LU.CON'C
                      +C.BRA_CT_LU.BRA_SB_RH'P*LOG((BRA_SB_RH(-1)+BRA_SB_EPA(-1))/BRA_SB_CPCI(-1))
                      +C.BRA_CT_LU.BRA_MA_RH'P*LOG((BRA_MA_RH(-1)+BRA_MA_EPA(-1))/BRA_MA_CPCI(-1))
                      +C.BRA_CT_LU.BRA_CT_RH'P*LOG((BRA_CT_RH(-1)+BRA_CT_EPA(-1))/BRA_CT_CPCI(-1))
                      +C.BRA_CT_LU.BRA_BN_RH'P*LOG((BRA_BN_RH..1ST(-1)+BRA_BN_EPA(-1))/BRA_BN_CPCI(-1))
                      +C.BRA_CT_LU.BRA_RI_RH'P*LOG((BRA_RI_RH(-1)+BRA_RI_EPA(-1))/BRA_RI_CPCI(-1))
                      +C.BRA_CT_LU.BRA_SCA_RH'P*LOG((BRA_SCA_RH(-1)
                      +BRA_SCA_EPA(-1))/BRA_SCA_CPCI(-1)+(BRA_SCA_RH(-2)+BRA_SCA_EPA(-2))/BRA_SCA_CPCI(-2))
                      +C.BRA_CT_LU.BRA_BV_RH'P*LOG((BRA_BV_RH(-1)+BRA_BV_EPQ(-1))/BRA_MD_CPCI(-1))
                      +LOG(R.BRA_CT_LU'POL),
```

```
BRA_BN_LU: LOG(BRA_BN_LU'N) = C.BRA_BN_LU.CON'C
                +C.BRA_BN_LU.BRA_SB_RH'P*LOG((BRA_SB_RH(-1)+BRA_SB_EPA(-1))/BRA_SB_CPCI(-1))
                +C.BRA_BN_LU.BRA_MA_RH'P*LOG((BRA_MA_RH(-1)+BRA_MA_EPA(-1))/BRA_MA_CPCI(-1))
                +C.BRA_BN_LU.BRA_CT_RH'P*LOG((BRA_CT_RH(-1)+BRA_CT_EPA(-1))/BRA_CT_CPCI(-1))
                +C.BRA_BN_LU.BRA_BN_RH'P*LOG((BRA_BN_RH..1ST(-1)+BRA_BN_EPA(-1))/BRA_BN_CPCI(-1))
                +C.BRA_BN_LU.BRA_RI_RH'P*LOG((BRA_RI_RH(-1)+BRA_RI_EPA(-1))/BRA_RI_CPCI(-1))
                +C.BRA_BN_LU.BRA_SCA_RH'P*LOG((BRA_SCA_RH(-1)
                +BRA_SCA_EPA(-1))/BRA_SCA_CPCI(-1)+(BRA_SCA_RH(-2)+BRA_SCA_EPA(-2))/BRA_SCA_CPCI(-2))
                +C.BRA_BN_LU.BRA_BV_RH'P*LOG((BRA_BV_RH(-1)+BRA_BV_EPQ(-1))/BRA_MD_CPCI(-1))
                +LOG(R.BRA_BN_LU'POL),

BRA_RI_LU: LOG(BRA_RI_LU'N) = C.BRA_RI_LU.CON'C
                +C.BRA_RI_LU.BRA_SB_RH'P*LOG((BRA_SB_RH(-1)+BRA_SB_EPA(-1))/BRA_SB_CPCI(-1))
                +C.BRA_RI_LU.BRA_MA_RH'P*LOG((BRA_MA_RH(-1)+BRA_MA_EPA(-1))/BRA_MA_CPCI(-1))
                +C.BRA_RI_LU.BRA_CT_RH'P*LOG((BRA_CT_RH(-1)+BRA_CT_EPA(-1))/BRA_CT_CPCI(-1))
                +C.BRA_RI_LU.BRA_BN_RH'P*LOG((BRA_BN_RH..1ST(-1)+BRA_BN_EPA(-1))/BRA_BN_CPCI(-1))
                +C.BRA_RI_LU.BRA_RI_RH'P*LOG((BRA_RI_RH(-1)+BRA_RI_EPA(-1))/BRA_RI_CPCI(-1))
                +C.BRA_RI_LU.BRA_SCA_RH'P*LOG((BRA_SCA_RH(-1)
                +BRA_SCA_EPA(-1))/BRA_SCA_CPCI(-1)+(BRA_SCA_RH(-2)+BRA_SCA_EPA(-2))/BRA_SCA_CPCI(-2))
                +C.BRA_RI_LU.BRA_BV_RH'P*LOG((BRA_BV_RH(-1)+BRA_BV_EPQ(-1))/BRA_MD_CPCI(-1))
                +LOG(R.BRA_RI_LU'POL),

BRA_SCA_LU: LOG(BRA_SCA_LU'N) = C.BRA_SCA_LU.CON'C
                +C.BRA_SCA_LU.BRA_SB_RH'P*LOG((BRA_SB_RH(-1)+BRA_SB_EPA(-1))/BRA_SB_CPCI(-1))
                +C.BRA_SCA_LU.BRA_MA_RH'P*LOG((BRA_MA_RH(-1)+BRA_MA_EPA(-1))/BRA_MA_CPCI(-1))
                +C.BRA_SCA_LU.BRA_CT_RH'P*LOG((BRA_CT_RH(-1)+BRA_CT_EPA(-1))/BRA_CT_CPCI(-1))
                +C.BRA_SCA_LU.BRA_BN_RH'P*LOG((BRA_BN_RH..1ST(-1)+BRA_BN_EPA(-1))/BRA_BN_CPCI(-1))
                +C.BRA_SCA_LU.BRA_RI_RH'P*LOG((BRA_RI_RH(-1)+BRA_RI_EPA(-1))/BRA_RI_CPCI(-1))
                +C.BRA_SCA_LU.BRA_SCA_RH'P*LOG((BRA_SCA_RH(-1)
                +BRA_SCA_EPA(-1))/BRA_SCA_CPCI(-1)+(BRA_SCA_RH(-2)+BRA_SCA_EPA(-2))/BRA_SCA_CPCI(-2))
                +C.BRA_SCA_LU.BRA_BV_RH'P*LOG((BRA_BV_RH(-1)+BRA_BV_EPQ(-1))/BRA_MD_CPCI(-1))
                +LOG(R.BRA_SCA_LU'POL),

BRA_BV_LU: LOG(BRA_BV_LU'N) = C.BRA_BV_LU.CON'C
                +C.BRA_BV_LU.BRA_SB_RH'P*LOG((BRA_SB_RH(-1)+BRA_SB_EPA(-1))/BRA_SB_CPCI(-1))
                +C.BRA_BV_LU.BRA_MA_RH'P*LOG((BRA_MA_RH(-1)+BRA_MA_EPA(-1))/BRA_MA_CPCI(-1))
                +C.BRA_BV_LU.BRA_CT_RH'P*LOG((BRA_CT_RH(-1)+BRA_CT_EPA(-1))/BRA_CT_CPCI(-1))
                +C.BRA_BV_LU.BRA_BN_RH'P*LOG((BRA_BN_RH..1ST(-1)+BRA_BN_EPA(-1))/BRA_BN_CPCI(-1))
                +C.BRA_BV_LU.BRA_RI_RH'P*LOG((BRA_RI_RH(-1)+BRA_RI_EPA(-1))/BRA_RI_CPCI(-1))
                +C.BRA_BV_LU.BRA_SCA_RH'P*LOG((BRA_SCA_RH(-1)
                +BRA_SCA_EPA(-1))/BRA_SCA_CPCI(-1)+(BRA_SCA_RH(-2)+BRA_SCA_EPA(-2))/BRA_SCA_CPCI(-2))
                +C.BRA_BV_LU.BRA_BV_RH'P*LOG((BRA_BV_RH(-1)+BRA_BV_EPQ(-1))/BRA_MD_CPCI(-1))
                +LOG(R.BRA_BV_LU'POL),

// SINCE MKCI COUNTS FOR ONLY 10% OF THE CATTLE HERD AND SINCE SOME DAIRY FARMS HAVE FIXED COST DUE
// TO THE MILKING EQUIPMENT AND BARNS IT IS PREFERABLE TO MAINTAIN THE ACTUAL MKCI SUPPLY FUNCTION
// WHICH IS INFLUENCED BY BOTH MILK PRICE AND CROP PRICES BUT WITH THE PROPER DYNAMIC WITH A LAGGED
// ENDOGENOUS VARIABLE AND TO LINK PASTURE LAND USED BY DAIRY FARMS TO THE NUMBERS OF MKCI BUT
// TAKING INTO ACCOUNT CHANGE IN INTENSITY WITH A NEGATIVE TIME TREND

BRA_MK_LU: LOG(BRA_MK_LU'N) = C.BRA_MK_LU.CON'C
                +C.BRA_MK_LU.BRA_MK_CI'C*LOG(BRA_MK_CI)
                +C.BRA_MK_LU.TRND'C*TRND
                +LOG(R.BRA_MK_LU'POL),

BRA_PA_LU: BRA_PA_LU'N = BRA_BV_LU
                +BRA_MK_LU,

// SECOND CROP
BRA_MA_AH..2ND: LOG(BRA_MA_AH..2ND'N) = C.BRA_MA_AH.CON'C
                +C.BRA_MA_AH.BRA_MA_RH'P*LOG((BRA_MA_RH(-1)+BRA_MA_EPA(-1))/BRA_MA_CPCI(-1))
                +C.BRA_MA_AH.BRA_WT_RH'P*LOG((BRA_WT_RH(-1)+BRA_WT_EPA(-1))/BRA_WT_CPCI(-1))
                +C.BRA_MA_AH.BRA_BN_RH'P*LOG((BRA_BN_RH..2ND(-1)+BRA_BN_EPA(-1))/BRA_BN_CPCI(-1))
                +LOG(R.BRA_MA_AH..2ND'POL),

BRA_BN_AH..2ND: LOG(BRA_BN_AH..2ND'N) = C.BRA_BN_AH.CON'C
                +C.BRA_BN_AH.BRA_MA_RH'P*LOG((BRA_MA_RH(-1)+BRA_MA_EPA(-1))/BRA_MA_CPCI(-1))
                +C.BRA_BN_AH.BRA_WT_RH'P*LOG((BRA_WT_RH(-1)+BRA_WT_EPA(-1))/BRA_WT_CPCI(-1))
                +C.BRA_BN_AH.BRA_BN_RH'P*LOG((BRA_BN_RH..2ND(-1)+BRA_BN_EPA(-1))/BRA_BN_CPCI(-1))
                +LOG(R.BRA_BN_AH..2ND'POL),

BRA_BN_QP: BRA_BN_QP'N = BRA_BN_AH*BRA_BN_YLD;


// SINCE WT IS CONSIDERED A SUBSTITUTE FOR RT IN RT_AH THROUGH SYMMETRY, AN EQUIVALENT CROSS
```

```
// IS CALCULATED
REPEQ BRA_WT_AH BRA_WT_AH: LOG(BRA_WT_AH) = C.BRA_WT_AH.CON'C
                +C.BRA_WT_AH.BRA_MA_RH'P*LOG((BRA_MA_RH(-1)+BRA_MA_EPA(-1))/BRA_MA_CPCI(-1))
                +C.BRA_WT_AH.BRA_WT_RH'P*LOG((BRA_WT_RH(-1)+BRA_WT_EPA(-1))/BRA_WT_CPCI(-1))
                +C.BRA_WT_AH.BRA_RT_RH'P*LOG((BRA_RT_RH(-1)+BRA_RT_EPA(-1))/BRA_RT_CPCI(-1))
                +C.BRA_WT_AH.BRA_BN_RH'P*LOG((BRA_BN_RH..2ND(-1)+BRA_BN_EPA(-1))/BRA_BN_CPCI(-1))
                +LOG(R.BRA_WT_AH);


//YIELD: THE DIFFERENCE BETWEEN MA_YLD SECOND AND FIRST CROP IS NOT SIGNIFICANT
// TO SIMPLIFY THE MODEL AGGREGATE YIELD ARE USED IN BOTH SYSTEM BUT THIS IS NOT THE CASE FOR BN

ADDEQ BOTTOM,
BRA_BN_YLD: LOG(BRA_BN_YLD'N) = C.BRA_BN_YLD.CON'C
                +C.BRA_BN_YLD.TRND'C*TRND
                +C.BRA_BN_YLD.BRA_BN_PP'P*LOG((BRA_BN_PP+BRA_BN_EPY)/BRA_BN_CPCI)
                +LOG(R.BRA_BN_YLD'POL),

BRA_BN_YLD..1ST: BRA_BN_YLD..1ST'N = (C.BRA_BN_YLD1.CON'C
                +C.BRA_BN_YLD1.BRA_BN_YLD'C*BRA_BN_YLD)*R.BRA_BN_YLD..1ST'POL,

BRA_BN_YLD..2ND: BRA_BN_YLD..2ND'N = (C.BRA_BN_YLD2.CON'C
                +C.BRA_BN_YLD2.BRA_BN_YLD'C*BRA_BN_YLD)*R.BRA_BN_YLD..2ND'POL,

BRA_BN_RH..1ST: BRA_BN_RH..1ST'N = 0.5*BRA_BN_PP*BRA_BN_YLD..1ST
                +0.3*BRA_BN_PP(-1)*BRA_BN_YLD..1ST(-1)
                +0.2*BRA_BN_PP(-2)*BRA_BN_YLD..1ST(-2),

BRA_BN_RH..2ND: BRA_BN_RH..2ND'N = 0.5*BRA_BN_PP*BRA_BN_YLD..2ND
                +0.3*BRA_BN_PP(-1)*BRA_BN_YLD..2ND(-1)
                +0.2*BRA_BN_PP(-2)*BRA_BN_YLD..2ND(-2);

//AREA HARVESTED AND CROPPING INDEX
// SB, CT, RI , PA AND SCA CRPI EXOGENOUS EQUAL TO 1, WT_CRPI EXOGENOUS EQUAL TO 0

REPEQ BRA_SB_AH BRA_SB_AH: BRA_SB_AH = BRA_SB_LU/BRA_SB_CRPI;

REPEQ BRA_CT_AH BRA_CT_AH: BRA_CT_AH = BRA_CT_LU/BRA_CT_CRPI;

REPEQ BRA_RI_AH BRA_RI_AH: BRA_RI_AH = BRA_RI_LU/BRA_RI_CRPI;

REPEQ BRA_SCA_AH BRA_SCA_AH: BRA_SCA_AH = BRA_SCA_LU/BRA_SCA_CRPI;

REPEQ BRA_MA_AH BRA_MA_AH: BRA_MA_AH = BRA_MA_LU
                +BRA_MA_AH..2ND;

ADDEQ BOTTOM,
BRA_BN_AH: BRA_BN_AH'N = BRA_BN_LU
                +BRA_BN_AH..2ND,

BRA_PA_AH: BRA_PA_AH'N = BRA_PA_LU/BRA_PA_CRPI,

BRA_WT_LU: BRA_WT_LU'N = BRA_WT_CRPI*BRA_WT_AH,

BRA_ME_LU: BRA_ME_LU'N = BRA_SB_LU
                +BRA_MA_LU
                +BRA_CT_LU
                +BRA_RI_LU
                +BRA_BN_LU
                +BRA_SCA_LU
                +BRA_PA_LU
                +BRA_OCG_AH
                +BRA_OOS_AH
                +BRA_RT_AH,

BRA_MA_CRPI: BRA_MA_CRPI'N = BRA_MA_LU/BRA_MA_AH,

BRA_BN_CRPI: BRA_BN_CRPI'N = BRA_BN_LU/BRA_BN_AH;

REPEQ BRA_ME_AH BRA_ME_AH: BRA_ME_AH = BRA_OCG_AH
                +BRA_CT_AH
                +BRA_OOS_AH
                +BRA_RI_AH
                +BRA_RT_AH
                +BRA_WT_AH
```

```
                +BRA_MA_AH
                +BRA_SB_AH
                +BRA_SCA_AH
                +BRA_BN_AH
                +BRA_PA_AH;

// RETURN PER HECTARE AND CPCI
// WITH THIS SPECIFICATION SCA IS THE SAME AS OTHERS, THE 0.5, 0.3 AND 0.2 IS VERY CLOSE
// TO THE DIFFERENCE IN YIELD IN THE FIRST, SECOND AND THIRD YEAR OF PRODUCTION

REPEQ BRA_SCA_RH BRA_SCA_RH: BRA_SCA_RH = 0.5*BRA_SCA_PP*BRA_SCA_YLD
                +0.3*BRA_SCA_PP(-1)*BRA_SCA_YLD(-1)
                +0.2*BRA_SCA_PP(-2)*BRA_SCA_YLD(-2);


// NEED NEW EQUATIONS BECAUSE THE INDEXING YEAR HAS CHANGED

REPEQ BRA_MA_CPCI BRA_MA_CPCI: BRA_MA_CPCI = BRA_MA_CPCI..SHSD*BRA_MA_PP(-1)/BRA_MA_PP..2014
                +BRA_MA_CPCI..SHEN*WLD_OIL_XP..BRA*BRA_ME_XR/(WLD_OIL_XP..2015*BRA_ME_XR..2015)
                +BRA_MA_CPCI..SHFT*WLD_FT_XP..BRA*BRA_ME_XR/(WLD_FT_XP..2015*BRA_ME_XR..2015)
                +BRA_MA_CPCI..SHTR*USA_ME_GDPD..BRA*BRA_ME_XR/(USA_ME_GDPD..2015*BRA_ME_XR..2015)
                +BRA_MA_CPCI..SHNT*BRA_ME_GDPD/BRA_ME_GDPD..2015;

REPEQ BRA_SB_CPCI BRA_SB_CPCI: BRA_SB_CPCI = BRA_SB_CPCI..SHSD*BRA_SB_PP(-1)/BRA_SB_PP..2014
                +BRA_SB_CPCI..SHEN*WLD_OIL_XP..BRA*BRA_ME_XR/(WLD_OIL_XP..2015*BRA_ME_XR..2015)
                +BRA_SB_CPCI..SHFT*WLD_FT_XP..BRA*BRA_ME_XR/(WLD_FT_XP..2015*BRA_ME_XR..2015)
                +BRA_SB_CPCI..SHTR*USA_ME_GDPD..BRA*BRA_ME_XR/(USA_ME_GDPD..2015*BRA_ME_XR..2015)
                +BRA_SB_CPCI..SHNT*BRA_ME_GDPD/BRA_ME_GDPD..2015;

REPEQ BRA_RI_CPCI BRA_RI_CPCI: BRA_RI_CPCI = BRA_RI_CPCI..SHSD*BRA_RI_PP(-1)/BRA_RI_PP..2014
                +BRA_RI_CPCI..SHEN*WLD_OIL_XP..BRA*BRA_ME_XR/(WLD_OIL_XP..2015*BRA_ME_XR..2015)
                +BRA_RI_CPCI..SHFT*WLD_FT_XP..BRA*BRA_ME_XR/(WLD_FT_XP..2015*BRA_ME_XR..2015)
                +BRA_RI_CPCI..SHTR*USA_ME_GDPD..BRA*BRA_ME_XR/(USA_ME_GDPD..2015*BRA_ME_XR..2015)
                +BRA_RI_CPCI..SHNT*BRA_ME_GDPD/BRA_ME_GDPD..2015;

REPEQ BRA_WT_CPCI BRA_WT_CPCI: BRA_WT_CPCI = BRA_WT_CPCI..SHSD*BRA_WT_PP(-1)/BRA_WT_PP..2015
                +BRA_WT_CPCI..SHEN*WLD_OIL_XP..BRA*BRA_ME_XR/(WLD_OIL_XP..2015*BRA_ME_XR..2015)
                +BRA_WT_CPCI..SHFT*WLD_FT_XP..BRA*BRA_ME_XR/(WLD_FT_XP..2015*BRA_ME_XR..2015)
                +BRA_WT_CPCI..SHTR*USA_ME_GDPD..BRA*BRA_ME_XR/(USA_ME_GDPD..2015*BRA_ME_XR..2015)
                +BRA_WT_CPCI..SHNT*BRA_ME_GDPD/BRA_ME_GDPD..2015;

REPEQ BRA_CT_CPCI BRA_CT_CPCI: BRA_CT_CPCI = BRA_CT_CPCI..SHSD*BRA_CT_PP(-1)/BRA_CT_PP..2014
                +BRA_CT_CPCI..SHEN*WLD_OIL_XP..BRA*BRA_ME_XR/(WLD_OIL_XP..2015*BRA_ME_XR..2015)
                +BRA_CT_CPCI..SHFT*WLD_FT_XP..BRA*BRA_ME_XR/(WLD_FT_XP..2015*BRA_ME_XR..2015)
                +BRA_CT_CPCI..SHTR*USA_ME_GDPD..BRA*BRA_ME_XR/(USA_ME_GDPD..2015*BRA_ME_XR..2015)
                +BRA_CT_CPCI..SHNT*BRA_ME_GDPD/BRA_ME_GDPD..2015;

REPEQ BRA_SCA_CPCI BRA_SCA_CPCI: BRA_SCA_CPCI = BRA_SCA_CPCI..SHSD*BRA_SCA_PP(-1)/BRA_SCA_PP..2013
                +BRA_SCA_CPCI..SHEN*WLD_OIL_XP..BRA*BRA_ME_XR/(WLD_OIL_XP..2014*BRA_ME_XR..2014)
                +BRA_SCA_CPCI..SHFT*WLD_FT_XP..BRA*BRA_ME_XR/(WLD_FT_XP..2014*BRA_ME_XR..2014)
                +BRA_SCA_CPCI..SHTR*USA_ME_GDPD..BRA*BRA_ME_XR/(USA_ME_GDPD..2014*BRA_ME_XR..2014)
                +BRA_SCA_CPCI..SHNT*BRA_ME_GDPD/BRA_ME_GDPD..2014;

ADDEQ BOTTOM, BRA_BN_CPCI: BRA_BN_CPCI'N = BRA_BN_CPCI..SHSD*BRA_BN_PP(-1)/BRA_BN_PP..2014
                +BRA_BN_CPCI..SHEN*WLD_OIL_XP..BRA*BRA_ME_XR/(WLD_OIL_XP..2015*BRA_ME_XR..2015)
                +BRA_BN_CPCI..SHFT*WLD_FT_XP..BRA*BRA_ME_XR/(WLD_FT_XP..2015*BRA_ME_XR..2015)
                +BRA_BN_CPCI..SHTR*USA_ME_GDPD..BRA*BRA_ME_XR/(USA_ME_GDPD..2015*BRA_ME_XR..2015)
                +BRA_BN_CPCI..SHNT*BRA_ME_GDPD/BRA_ME_GDPD..2015;

// RUMINANT INTERACTION

ADDEQ BOTTOM,
BRA_BV_YLD: BRA_BV_YLD'N = BRA_BV_QP/BRA_BV_LU,

BRA_BV_RH: BRA_BV_RH'N = 0.5*BRA_BV_PP*BRA_BV_YLD
                +0.3*BRA_BV_PP(-1)*BRA_BV_YLD(-1)
                +0.2*BRA_BV_PP(-2)*BRA_BV_YLD(-2);

// SINCE THE ECONOMIC DECISION IS ALREADY TAKEN IN THE BA_LU EQUATION, NO NEED TO REPEAT HERE. THE
// PRESENCE OF BVPP AND POSITIVE TREND IS TO CAPTURE GROWING INTENSITY DRIVEN BY HIGHER PRICE AND
// BETTER MANAGEMENT

CHANGESYM COEFFICIENT C.BRA_BV_CI.BRA_BV_PP C.BRA_BV_CI.LAG;

REPEQ BRA_BV_CI BRA_BV_CI: LOG(BRA_BV_CI/BRA_BV_LU) = C.BRA_BV_CI.CON
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                    +C.BRA_BV_CI.TRND'C*TRND
                    +C.BRA_BV_CI.BRA_BV_PP'C*LOG((BRA_BV_PP(-1)+BRA_BV_EPQ(-1))/BRA_MD_CPCI(-1))
                    +C.BRA_BV_CI.LAG'C*LOG(BRA_BV_CI(-1)/BRA_BV_LU(-1))
                    +LOG(R.BRA_BV_CI);

// TRANSPORT COST: 97% OF WT_AH IS CLOSE TO PORT SO NO INFLUENCE FROM INTERNAL TRANSPORT COST
// 86% OF SCA_AH IS CLOSE TO PORT SO NO INFLUENCE FROM INTERNAL TRANSPORT COST
// THE AH..FAR ARE THE SHARE OF AH THAT ARE IN THE CERRADOS AND AMAZONIA REGIONS

REPEQ BRA_CT_EX BRA_CT_EX: LOG(BRA_CT_EX) = C.BRA_CT_EX.CON
                    +C.BRA_CT_EX.BRA_CT_PP*LOG(BRA_CT_PP
                    /((BRA_CT_EXP-0.94*BRA_SB_TC)*(1-BRA_CT_TAVE/100)))
                    +LOG(R.BRA_CT_EX);

REPEQ BRA_SB_EX BRA_SB_EX: LOG(BRA_SB_EX) = C.BRA_SB_EX.CON
                    +C.BRA_SB_EX.BRA_SB_PP*LOG(BRA_SB_PP
                    /((BRA_SB_EXP-BRA_SB_AH..FAR*BRA_SB_TC)*(1-BRA_SB_TAVE/100)))
                    +LOG(R.BRA_SB_EX);

REPEQ BRA_MA_EX BRA_MA_EX: LOG(BRA_MA_EX) = C.BRA_MA_EX.CON
                    +C.BRA_MA_EX.BRA_MA_PP*LOG(BRA_MA_PP
                    /((BRA_MA_EXP-BRA_MA_AH..FAR*BRA_SB_TC)*(1-BRA_MA_TAVE/100)))
                    +LOG(R.BRA_MA_EX);

REPEQ BRA_RI_EX BRA_RI_EX: LOG(BRA_RI_EX) = C.BRA_RI_EX.CON
                    +C.BRA_RI_EX.BRA_RI_PP*LOG(BRA_RI_PP
                    /((BRA_RI_EXP-BRA_RI_AH..FAR*BRA_SB_TC)*(1-BRA_RI_TAVE/100)))
                    +LOG(R.BRA_RI_EX);

DELEQ BRA_SB_AH..NTH BRA_SB_AH..STH BRA_SB_PP..NTH BRA_SB_PP..STH BRA_SB_RH..NTH BRA_SB_RH..STH;

DELSYM BRA_SB_AH..NTH BRA_SB_AH..STH BRA_SB_PP..NTH BRA_SB_PP..STH BRA_SB_RH..NTH BRA_SB_RH..STH;

REPEQ BRA_BD_QC BRA_BD_QC: BRA_BD_QC = BRA_BD_QCS..EFF*BRA_DIE_QC/C.WLD_BD_ERAT..DIE;

DELSYM NOWARN ALL;

//=================================================================================================
// PART 2: INTRODUCTION OF NEW ELASTICITIES AND NEW ESTIMATION OF INTERCEPTS DUE TO THE NEW
//         ELASTICITIES OR NEW DATA LIKE THE CPCIs
//=================================================================================================

ACCESS NEWBRACOEF2 type trolltxt id NEWBRACOEF2.txt mode C;
SEARCH NEWBRACOEF2 ;

//THIS DATABASE CONTAINS THE NEW SERIES
// NEW SERIES CREATED WITH DO COMMANDS AND MODIFICATIONS TO EXISTING SERIES IN BASELINE2016
// INCLUDING THE R FACTOR THAT DID NOT HAVE VALUE OF 1 OVER THE HISTORICAL PERIOD

//ACCESS BRADATAMODIF type trolltxt id BRADATAMODIF.txt mode c;
//&upload "BRADATAMODIF.csv" "BRADATAMODIF";
ACCESS BRADATAMODIF type trolltxt id BRADATAMODIF.txt mode r;
SEARCH BRADATAMODIF ;

ACCESS mergedBaseline2026 type trolltxt id .\..\ModelTags\EC2016\mergedBaseline2026.txt mode r;
SEARCH mergedBaseline2026;

ACCESS mergedEUcoefs type trolltxt id .\..\ModelTags\EC2016\mergedEUcoefs.txt mode r;
SEARCH mergedEUcoefs;

DO C.BRA_SB_LU.BRA_SB_RH            = 0.453;
DO C.BRA_SB_LU.BRA_MA_RH            = -0.25;
DO C.BRA_SB_LU.BRA_CT_RH            = -0.0874;
DO C.BRA_SB_LU.BRA_RI_RH            = -0.0416;
DO C.BRA_SB_LU.BRA_BN_RH            = -0.0324;
DO C.BRA_SB_LU.BRA_SCA_RH           = -0.0168;
DO C.BRA_SB_LU.BRA_BV_RH            = -0.0918;
DO C.BRA_MA_LU.BRA_SB_RH            = -0.0416;
DO C.BRA_MA_LU.BRA_MA_RH            = 0.1955;
DO C.BRA_MA_LU.BRA_CT_RH            = -0.0208;
DO C.BRA_MA_LU.BRA_RI_RH            = -0.0093;
DO C.BRA_MA_LU.BRA_BN_RH            = -0.0118;
DO C.BRA_MA_LU.BRA_SCA_RH           = -0.0087;
DO C.BRA_MA_LU.BRA_BV_RH            = -0.0071;
DO C.BRA_CT_LU.BRA_SB_RH            = -0.007;
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DO C.BRA_CT_LU.BRA_MA_RH                = -0.029;
DO C.BRA_CT_LU.BRA_CT_RH                = 0.2385;
DO C.BRA_CT_LU.BRA_RI_RH                = -0.0002;
DO C.BRA_CT_LU.BRA_BN_RH                = -0.0003;
DO C.BRA_CT_LU.BRA_SCA_RH               = -0.0017;
DO C.BRA_CT_LU.BRA_BV_RH                = -0.0007;
DO C.BRA_RI_LU.BRA_SB_RH                = -0.0109;
DO C.BRA_RI_LU.BRA_MA_RH                = -0.0109;
DO C.BRA_RI_LU.BRA_CT_RH                = -0.0019;
DO C.BRA_RI_LU.BRA_RI_RH                = 0.1429;
DO C.BRA_RI_LU.BRA_BN_RH                = -0.0119;
DO C.BRA_RI_LU.BRA_SCA_RH               = -0.0036;
DO C.BRA_RI_LU.BRA_BV_RH                = -0.0033;
DO C.BRA_BN_LU.BRA_SB_RH                = -0.0027;
DO C.BRA_BN_LU.BRA_MA_RH                = -0.013;
DO C.BRA_BN_LU.BRA_CT_RH                = -0.0007;
DO C.BRA_BN_LU.BRA_RI_RH                = -0.0012;
DO C.BRA_BN_LU.BRA_BN_RH                = 0.0978;
DO C.BRA_BN_LU.BRA_SCA_RH               = -0.0001;
DO C.BRA_BN_LU.BRA_BV_RH                = -0.003;
DO C.BRA_SCA_LU.BRA_SB_RH               = -0.0837;
DO C.BRA_SCA_LU.BRA_MA_RH               = -0.1563;
DO C.BRA_SCA_LU.BRA_CT_RH               = -0.0195;
DO C.BRA_SCA_LU.BRA_RI_RH               = -0.0126;
DO C.BRA_SCA_LU.BRA_BN_RH               = -0.0048;
DO C.BRA_SCA_LU.BRA_SCA_RH              = 0.4004;
DO C.BRA_SCA_LU.BRA_BV_RH               = -0.025;
DO C.BRA_BV_LU.BRA_SB_RH                = -0.0334;
DO C.BRA_BV_LU.BRA_MA_RH                = -0.0202;
DO C.BRA_BV_LU.BRA_CT_RH                = -0.0102;
DO C.BRA_BV_LU.BRA_RI_RH                = -0.0075;
DO C.BRA_BV_LU.BRA_BN_RH                = -0.0042;
DO C.BRA_BV_LU.BRA_SCA_RH               = -0.0046;
DO C.BRA_BV_LU.BRA_BV_RH                = 0.1021;
DO C.BRA_MA_AH.BRA_MA_RH                = 1.7;
DO C.BRA_MA_AH.BRA_BN_RH                = -0.15;
DO C.BRA_MA_AH.BRA_WT_RH                = -0.182;
DO C.BRA_BN_AH.BRA_MA_RH                = -0.63;
DO C.BRA_BN_AH.BRA_BN_RH                = 0.176;
DO C.BRA_BN_AH.BRA_WT_RH                = -0.178;
DO C.BRA_WT_AH.BRA_MA_RH                = -0.89;
DO C.BRA_WT_AH.BRA_BN_RH                = -0.15;
DO C.BRA_WT_AH.BRA_RT_RH                = -0.023;
DO C.BRA_WT_AH.BRA_WT_RH                = 2.41;
DO C.BRA_BN_YLD.BRA_BN_PP               = 0.1;
DO C.BRA_BD_QP..VL.BRA_BD_MAR           = 0.59;

BOUNDS 1995A TO 2014A;
OLSMOD BRA_BN_YLD;
FILECOEF NEWBRACOEF2;
OLSMOD BRA_BN_YLD..1ST;
FILECOEF NEWBRACOEF2;
OLSMOD BRA_BN_YLD..2ND;
FILECOEF NEWBRACOEF2;
BOUNDS 2012A TO 2015A;
OLSMOD BRA_SB_YLD;
FILECOEF NEWBRACOEF2;
OLSMOD BRA_MA_YLD;
FILECOEF NEWBRACOEF2;
OLSMOD BRA_CT_YLD;
FILECOEF NEWBRACOEF2;
OLSMOD BRA_RI_YLD;
FILECOEF NEWBRACOEF2;
OLSMOD BRA_SCA_YLD;
FILECOEF NEWBRACOEF2;
OLSMOD BRA_WT_YLD;
FILECOEF NEWBRACOEF2;
OLSMOD BRA_SB_LU;
FILECOEF NEWBRACOEF2;
OLSMOD BRA_CT_LU;
FILECOEF NEWBRACOEF2;
OLSMOD BRA_RI_LU;
FILECOEF NEWBRACOEF2;
OLSMOD BRA_SCA_LU;
FILECOEF NEWBRACOEF2;
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BOUNDS 2012A TO 2014A;
OLSMOD BRA_MA_LU;
FILECOEF NEWBRACOEF2;
OLSMOD BRA_BV_LU;
FILECOEF NEWBRACOEF2;
OLSMOD BRA_BN_LU;
FILECOEF NEWBRACOEF2;
OLSMOD BRA_MA_AH..2ND;
FILECOEF NEWBRACOEF2;
OLSMOD BRA_BN_AH..2ND;
FILECOEF NEWBRACOEF2;
BOUNDS 2012A TO 2015A;
OLSMOD BRA_WT_AH;
FILECOEF NEWBRACOEF2;
OLSMOD BRA_SB_EX;
FILECOEF NEWBRACOEF2;
OLSMOD BRA_MA_EX;
FILECOEF NEWBRACOEF2;
OLSMOD BRA_CT_EX;
FILECOEF NEWBRACOEF2;
OLSMOD BRA_RI_EX;
FILECOEF NEWBRACOEF2;
BOUNDS 2003A TO 2014A;
OLSMOD BRA_MK_LU;
FILECOEF NEWBRACOEF2;
BOUNDS 1996A TO 2014A;
OLSMOD BRA_BV_CI;
FILECOEF NEWBRACOEF2;
BOUNDS 2012A TO 2015A;
OLSMOD BRA_BD_QP..VL;
FILECOEF NEWBRACOEF2;

//==========================================================================================
// PART 3: CALIBRATION
//==========================================================================================

CHANGESYM ENDOGENOUS
          R.BRA_MA_LU R.BRA_SB_LU R.BRA_RI_LU R.BRA_CT_LU R.BRA_BV_LU R.BRA_SCA_LU R.BRA_BN_LU
          R.BRA_MK_LU R.BRA_BN_AH..2ND R.BRA_BN_YLD R.BRA_BN_YLD..1ST R.BRA_BN_YLD..2ND
          R.BRA_MA_AH..2ND R.BRA_SB_YLD R.BRA_WT_YLD R.BRA_MA_YLD R.BRA_CT_YLD R.BRA_SCA_YLD
          R.BRA_RI_YLD R.BRA_WT_AH R.BRA_SB_EX R.BRA_CT_EX R.BRA_MA_EX R.BRA_RI_EX R.BRA_BV_CI
          R.BRA_ET_QCS..FFV R.BRA_BD_QP..VL ;

CHANGESYM EXOGENOUS
          BRA_MA_LU BRA_SB_LU BRA_RI_LU BRA_CT_LU BRA_BV_LU BRA_SCA_LU BRA_BN_LU
          BRA_MK_LU BRA_BN_AH..2ND BRA_BN_YLD BRA_BN_YLD..1ST BRA_BN_YLD..2ND BRA_MA_AH..2ND
          BRA_SB_YLD BRA_WT_YLD BRA_MA_YLD BRA_CT_YLD BRA_SCA_YLD BRA_RI_YLD BRA_WT_AH
          BRA_SB_EX BRA_CT_EX BRA_MA_EX BRA_RI_EX BRA_BV_CI BRA_ET_FL BRA_BD_QP..VL ;

SIMULATE;

INPUT quiterr .\..\MACROS\CONOPT.inp;

SIMSTART 2017A 1990A;
DOTIL 2026A;

DELACCESS all;DELSEARCH all;

ACCESS BRAINPUT2 type trolltxt id BRAINPUT2.txt mode C;
SEARCH BRAINPUT2 w;

FILESIM BRAINPUT2;

DELACCESS all;DELSEARCH all;

// REPRODUCING THE BASELINE
ACCESS BRAINPUT2 type trolltxt id BRAINPUT2.txt mode R;
SEARCH BRAINPUT2 ;

ACCESS NEWBRACOEF2 type trolltxt id NEWBRACOEF2.txt mode R;
SEARCH NEWBRACOEF2 ;

ACCESS mergedEUcoefs type trolltxt id .\..\ModelTags\EC2016\mergedEUcoefs.txt mode r;
SEARCH mergedEUcoefs;
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CHANGESYM EXOGENOUS
                R.BRA_MA_LU R.BRA_SB_LU R.BRA_RI_LU R.BRA_CT_LU R.BRA_BV_LU R.BRA_SCA_LU R.BRA_BN_LU
                R.BRA_MK_LU R.BRA_BN_AH..2ND R.BRA_BN_YLD R.BRA_BN_YLD..1ST R.BRA_BN_YLD..2ND
                R.BRA_MA_AH..2ND R.BRA_SB_YLD R.BRA_WT_YLD R.BRA_MA_YLD R.BRA_CT_YLD R.BRA_SCA_YLD
                R.BRA_RI_YLD R.BRA_WT_AH R.BRA_SB_EX R.BRA_CT_EX R.BRA_MA_EX R.BRA_RI_EX R.BRA_BV_CI
                R.BRA_ET_QCS..FFV R.BRA_BD_QP..VL ;

CHANGESYM ENDOGENOUS
                BRA_MA_LU BRA_SB_LU BRA_RI_LU BRA_CT_LU BRA_BV_LU BRA_SCA_LU BRA_BN_LU
                BRA_MK_LU BRA_BN_AH..2ND BRA_BN_YLD BRA_BN_YLD..1ST BRA_BN_YLD..2ND BRA_MA_AH..2ND
                BRA_SB_YLD BRA_WT_YLD BRA_MA_YLD BRA_CT_YLD BRA_SCA_YLD BRA_RI_YLD BRA_WT_AH
                BRA_SB_EX BRA_CT_EX BRA_MA_EX BRA_RI_EX BRA_BV_CI BRA_ET_FL BRA_BD_QP..VL ;

SIMULATE;
INPUT quiterr .\..\MACROS\CONOPT.inp;
SIMSTART 2017A 1990A;
DOTIL 2026A;

ACCESS BASETEST2 type trolltxt id BASETEST2.txt mode C;
SEARCH BASETEST2 ;

FILESIM BASETEST2;

ACCESS mergedBaseline2026 type trolltxt id .\..\ModelTags\EC2016\mergedBaseline2026.txt mode r;
&PRTDSET VALUE ER PCER, VARI WLD_MA_XP WLD_RI_XP WLD_WT_XP WLD_SB_XP WLD_CT_XP WLD_SUR_XP
ATL_BV_XP,RANGE 2017A TO 2026A,DSETS mergedBaseline2026 BASETEST2;
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