Does structure matter?

Exploring the impact of model structure on model results

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Introduction

At times policymakers or researchers from different fields object to CGE models for being black boxes. At the same time especially policy-makers tend to object to simplifications of reality, and their own desired policies in particular. Ironically the black-box properties of CGE models stems from their economy-wide coverage where everything depends on everything else. In other words, the lack of simplification of economy-wide relationships creates interdependencies that make interpretation of model results at times seem like black art.

The GTAP short-course could then be seen as the Hogwarts School of Witchcraft and Wizardry for CGE analysis. This course focuses on interpreting results from CGE analysis with dedicated tools like decomposition analysis and AnalyzeGE, underscoring the challenge of shedding some light in the black box. Understanding the mechanism driving model results is key to providing policy-makers with a more in-depth understanding of how their proposed policies may change behavior and thus the economy, an understanding which is not well served by simply listing changes in key economic variables moving up or down (so-called 'elevator-economics').

Adding to the complexity of CGE models are the numerous extensions made to the basic CGE model exemplified by the standard GTAP model. These extensions aim at better capturing features of the economy for specific research questions, for example the impact of agricultural policies, GHG emissions, biofuel use, migration and so on. In practice institutions working extensively with CGE models develop their own model which grows in complexity over time. Eventually it is no longer obvious how the extensions of the model affect results and whether there are interactions between extensions (which may indicate unexpected mechanisms appearing in reality). To our knowledge no systematic comparisons of the impact of different model extensions and their interactions on model results are available.

The objective of this paper is to provide such an analysis of sensitivity of model results to model structure by analyzing the impact of nested-CES production structure on model results. For this analysis we use a new version of the LEITAP model (a GTAP-based CGE model developed at the LEI). This version of the LEITAP model has been developed to facilitate changes in model structure to address specific research questions. Based on a set of parameters capturing all available model choices a sequence of programs generates the appropriate data and model structure. This program-based approach makes the choices made in setting-up the model transparent, a necessity in the team-based analyses performed at LEI.

We generate three versions of the model (each with the same regional and sectoral aggregation): a 'plain vanilla' GTAP version with all default GTAP parameters, a GTAP-AGR version which introduces region- and sector specific elasticities and a LEITAP version which adds fertilizer-land substitution for crop sectors and feed-land substitution for livestock sectors. We then run the Doha trade liberalization scenario with each of these three models and compare results to assess the impact of an extended nested-CES structure on model results.

This analysis of the production structure is the first of a set of model assessments planned for at LEI to systematically explore the various extensions (and their interactions) that are part of the LEITAP model. First experiences with the new model indicate the added value of being able to effortlessly change the model structure, inviting researchers to esxplore the impact of these variations on their analyses. We also find that having a list of model choices that need to be made at the start of the modeling exercise increases both awareness and discussion of the different ways of modeling the economy, something which is easily lost when working with a complex CGE model.

Modeling approach

As other institutions involved in CGE modeling, LEI has developed its own version of a GTAP-based model called LEITAP. Over the years LEITAP has been extended to address a variety of policy-issues. The resulting model is complex and less flexible in terms of aggregations than the standard GTAP model. At the same time the modeling team at LEI became more international, increasing staff turnover and thus the need for model transparency to get new team members up to speed. As a result a restructuring effort started with aim of increasing model transparency, facilitate adjustment of the model to specific research questions and testing the (combined) impact of various model adjustments.

A new modeling philosophy

The new LEITAP has been build using a software program developed at LEI, Gtree, which builds the GEMPACK-compatible code from a large set of hierarchically ordered text files. The ordering of the files provides a view of the overall structure of the model. It also enhances the benefits of version control since changes in model code can be immediately traced to a limited number of text files.

The first step in developing the new LEITAP model was to restructure the standard GTAP model (V6.2, September 2003) using Gtree. The model code was split in a large number of text files that highlight the structure of the model. Figure 1 provides a screenshot of Gtree to illustrate the structure of the model. It clearly shows that the LEITAP model is based on the standard GTAP model which has been restructured in different modules. The screenshot highlights the file describing eth topnest of the standard GTAP production structure (hence called GTAPfirms_topnest.gmp). It illustrates the reliance on sets to control the structure of the model. The standard GTAP equations have not been changed, but their domain has been limited to regions with a plain production structure (GPROD_REG). This single file describing the topnest of the production structure contains all relevant definitions in one file to facilitate the understanding of this specific part of the model.

Using sets to govern the model structure are key to the philosophy of the restructured LEITAP model. It however also implies that a large number of sets need to be defined when the model is extended, with the contents of these sets depending on the chosen model aggregation as well as choices on the structure of the economy.

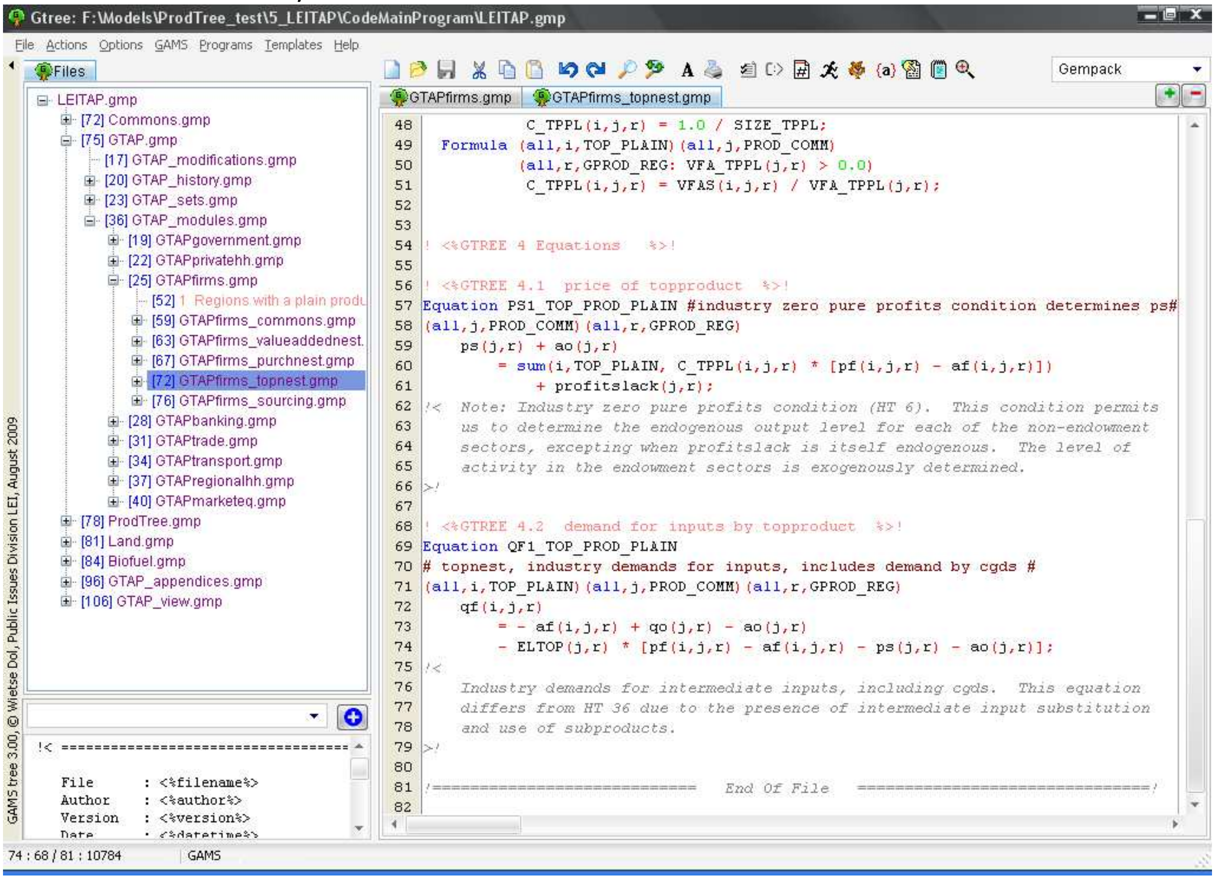


Figure 1: Screenshot of the LEITAP model in Gtree

To keep the wide range of choices manageable all data manipulations are coded in GEMPACK, providing flexibility as well as transparency of modeling choices. The result is a step-wise approach to constructing an operational model depicted in figure 2. The modeling sequence starts with aggregating the standard GTAP data using GTAPagg, thus allowing full flexibility in terms of regional and sectoral aggregation.

These choices on model aggregation are then used to create a set of parameters that govern the model structure (ModelChoice). In the case of the extended production structure with nested-CES functions, for example, regions that will not have the extension need to be defined through a parameter REG_GPROD_CH(reg). The dimensions of this parameter (i.e. the set REG) depend on the choices made in GTAPagg. The default value of this parameter is 0, implying that none of the regions has a standard GTAP production structure.

The choices made through parameters like REG_GPROD_CH(reg) are used in the next step LEITAPagg to generate sets for LEITAP which are consistent with the chosen model aggregation and structure. When generating the sets a number of consistency checks are applied. For example, in case of one (or more) regions have an extended production tree (i.e. the ProdTRee module of LEITAP is active) there is a check if all sectors have been assigned to a specific tree once. Then for all trees that are active there is a check if all inputs have been assigned to a nest once. The checks are designed such that if a module is not active no further choices need to be made. In other words, the chosen complexity of the model determines the number of choices to be made. This approach allows new users of the model to start with plain vanilla GTAP and step-by-step increase the complexity of the model.

GTAPagg	Aggregate standard GTAP data to chosen model aggregation of regions and sectors
⇓	
ModelChoice	Choose the desired model structure (subsets) through parameters that depend on chosen model aggregation
⇓	
LEITAPagg	Aggregate additional data for LEITAP based on chosen model structure
⇓	
ModifyData	Modify key model inputs if needed
⇓	
BaselineData	Create macro shocks (GDP and population) for each baseline period
⇓	
LEITAP	Run the LEITAP model

Figure 2: Steps in creating an operational version of the LEITAP model

LEITAPagg also, as the name suggests, aggregates additional data needed for extensions to LEITAP to the chosen model structure. This aggregation depends on the model choices made. In the case of the nested-CES production structures, for example, modelers can assign sectors to any of the nests which affects the relevant elasticities for each nest.

To maintain full flexibility all additional data for the LEITAP model need to be supplied at disaggregated sector and regional level. Since extensions are generally developed for a specific case data-quality may vary by sector and or region. Varying the aggregation can then result in model parameters that are undesirable. Model parameters (at the aggregated level) can be changed in the ModifyData step by adjusting a basic bit of GEMPACK code. Modifying data through code is used to make changes tractable, which is further enhanced by the versioning system used which can track changes in code but not in data-values. The output of the ModifyData step is a set of files which together with the LEITAP-code creates an operational model. The BaselineData step generates a datafile with macro shocks (projected changes in population and GDP) for each of the user-specified baseline periods.

GTAPagg and Modelchoice are the crucial steps

Defining the model aggregation is always a crucial start of the modeling exercise. Having not enough detail at regional or sectoral level can hamper adequate answers to policy questions at stake, while too much detail can increases solution times to such an extent that no analysis is possible. The flexiblity offered by LEITAP adds to the aggregation discussion a deliberation of the appropriate structure of the model by region and by sector.

Modules are activated by assigning regions to the associated sets. For example, one can choose to have the extended production structures only for some key regions and use the standard GTAP structure in others. This allows more regional detail with reasonable solution times, while having the desired production detail where needed. Furthermore, although the structure of the different production trees is fixed, the allocation of inputs to nests of a specific production structures is fully flexible. One can thus simplify structures by leaving sets in a specific branch empty.

The implication of the flexibility offered by LEITAP is a careful discussion at the start of the modeling exercise of the properties of the economy being studied, in terms of aggregation but also in terms of the structure of the production structure by region and sector (as well as the presence of endogenous land supply, biofuels and other extensions in LEITAP). Once these decisions are made by setting the parameters, all necessary files are generated effortlessly by a set of batch files.

To make well-informed decisions on the modeling structure, the implications of the different modules (and their combinations) on model results need to be understood. The focus of the current paper is to assess the impacts of changes in production structure on model results. The palette of choices is depicted in the annex, providing the structure of five alternative production structures:

1) *Plain*: two-level as in 'plain vanilla' GTAP[1];
2) *Fertilizer*: four-level, designed for modeling fertilizer-land interactions;
3) *Feed*: five-level, designed for modeling feed-land interactions;
4) *Electricity*: six-level, designed for modeling energy-substitution in electricity production;
5) *Petroleum*: eight-level, designed for modeling energy-substitution in petroleum production.

Note that although the naming is in line with the purpose for which the structures are designed (and in line with which substitution parameters have been defined), the allocation of inputs to nests is fully flexible. These structures could thus be used for any type of production structure with the same (or a smaller) number of nests. We will illustrate this in this application by using only 3 of the production trees and for two of these use only part of the available nests.

Data and scenarios

Whereas normally different scenarios are used to assess the implications of policy options, here our interest is in the implications of model structure on results. We therefore use the same scenario while changing the model aggregation and the way in which production is structured. We then compare the results for a key set of variables. This approach implies that we need to define a reference scenario and the permutations of LEITAP.

Reference scenario

The exploration of the impact of model structure on model results is the first of a series of tests to which the restructure LEITAP model will be subjected. Although one may prefer a simple scenario, for

[1] The production structure is a little less 'plain vanilla' than in the standard GTAP V6.2 model. We incorporated the GTAP-AGR structure with an additional purchased inputs nest for intermediate inputs. Through an appropriate choice of model parameters this structure can be simplified to the standard GTAP structure, which will be the starting point of our sensitivity analysis.

example affecting only sector in one region, to maximize tractability of the results we also like to know the impact of model structure for real world scenarios. To balance these two interests we use a realistic Doha-scenario, but ignore details issues like treatment of sensitive products or phasing in of tariff reductions. More specifically we run the models for three time periods:

1. 2004 – 2007: macro shocks to mirror projected GDP and population growth[2];

2. 2007 – 2013: macro shocks to mirror projected GDP and population growth + removal of tariffs within the EU27 to capture accession of Bulgaria and Romania;

3. 2007 – 2013: macro shocks to mirror projected GDP and population growth + reduction of tariffs according to possible Doha agreement[3] + removal of all export subsidies.

To keep the analysis manageable we will focus on the last period (2013-2020) in which the Doha agreements in implemented.

Model - region and sector aggregations

We run the model with GTAP data Version 7.1 (112 regions). Since our main interest is on the production structure we keep detail in terms of sectors while limiting the number of regions in the model to keep solution times acceptable. This results in 20 sectors[4] and 10 regions (see table 1 and table 2).

Table 1: regional aggregation

Name	GTAP regions included
EU-27	Austria; Belgium; Cyprus; Czech Republic; Denmark; Estonia; Finland; France; Germany; Greece; Hungary; Ireland; Italy; Latvia; Lithuania; Luxembourg; Malta; Netherlands; Poland; Portugal; Slovakia; Slovenia; Spain; Sweden; United Kingdom; Bulgaria; Romania.
Europe & Russian Federation	Switzerland; Norway; Rest of EFTA; Albania; Belarus; Croatia; Russian Federation; Ukraine; Rest of Eastern Europe; Rest of Europe; Kazakhstan; Kyrgyztan; Rest of Former Soviet Union; Armenia; Azerbaijan; Georgia.
NAFTA	Canada; United States of America; Mexico.
Rest of America	Rest of North America; Argentina; Bolivia; Chile; Colombia; Ecuador; Paraguay; Peru; Uruguay; Venezuela; Rest of South America; Costa Rica; Guatemala; Nicaragua; Panama; Rest of Central America; Caribbean.
Brazil	Brazil.
Oceania, Japan, Korea, Taiwan	Australia; New Zealand; Rest of Oceania; Japan; Korea; Taiwan.
China & Hong Kong	China; Hong Kong.
Rest of Asia	Rest of East Asia; Cambodia; Indonesia; Lao People's Democratic Republ; Malaysia;

[2] Projected GDP and population are taken from ERS-USDA data: http://www.ers.usda.gov/Data/Macroeconomics/#BaselineMacroTables
[3] Tariff shocks are computed using TASTE, specification of Doha agreement is derived from the December 6th 2008 modalities for agriculture and non-agriculture.
[4] Initially we used 23 sector aggregation with the energy sectors separated. This however caused major problems in the gas sector for China. Since these sectors are not essential for the current analysis we aggregated the energy sectors in a single sector which solved the problem for now, leaving this data issue to be solved to be addressed at another time.

	Philippines; Singapore; Thailand; Viet Nam; Rest of Southeast Asia; Bangladesh; India; Pakistan; Sri Lanka; Rest of South Asia.
North Africa & Middle East	Iran Islamic Republic of; Turkey; Rest of Western Asia; Egypt; Morocco; Tunisia; Rest of North Africa.
Sub-Saharan Africa	Nigeria; Senegal; Rest of Western Africa; Central Africa; South Central Africa; Ethiopia; Madagascar; Malawi; Mauritius; Mozambique; Tanzania; Uganda; Zambia; Zimbabwe; Rest of Eastern Africa; Botswana; South Africa; Rest of South African Customs .

Table 2: sector aggregation

Description	**GTAP sectors included**
Paddy and processed rice	Paddy rice; Processed rice.
Wheat	Wheat.
Cereal grains not wheat	Cereal grains nec.
Oil seeds	Oil seeds.
Sugar cane and beet, sugar	Sugar cane, sugar beet.
Vegetables, fruits, nuts	Vegetables, fruit, nuts.
Other crops	Plant-based fibers; Crops nec.
Cattle, sheep, goats, horses	Cattle,sheep,goats,horses; Wool, silk-worm cocoons; Meat: cattle,sheep,goats,horse.
Animal products nec	Animal products nec; Meat products nec.
Raw milk	Raw milk.
Dairy products	Dairy products.
Sugar	Sugar.
Vegetable oils and fats	Vegetable oils and fats.
Food nec mainly compound feed	Food products nec.
Other agro-food products	Fishing; Beverages and tobacco products.
Forestry	Forestry.
Fosil energy sectors	Coal; Oil; Gas; Petroleum, coal products; Electricity; Gas manufacture, distribution.
Chemical, rubber,plastic prods	Chemical,rubber,plastic prods.
Industry	Minerals nec; Textiles; Wearing apparel; Leather products; Wood products; Paper products, publishing; Mineral products nec; Ferrous metals; Metals nec; Metal products; Motor vehicles and parts; Transport equipment nec; Electronic equipment; Machinery and equipment nec; Manufactures nec.
Services	Water; Construction; Trade; Transport nec; Sea transport; Air transport; Communication; Financial services nec; Insurance; Business services nec; Recreation and other services; PubAdmin/Defence/Health/Educat; Dwellings.

Model - production structures

Our focus is on assessing the impact of production structure on model outcomes and we therefore vary models only in terms of production structure. In the case of the LEITAP model this implies that we exclude all extensions expect for the extended production tree module. Next to a set-up which replicates the plain vanilla GTAP model we also run a model with a GTAP-AGR production structure which allows (for agricultural sectors) substitution among intermediates as well as between value-added and intermediates, and makes the substitution elasticity in the value-added nest region-specific.

Since this analysis is the first assessment of the behavior of the new LEITAP model we limited the extensions of the production structure to introducing fertilizer-land interactions in crop sectors and feed-land interactions in livestock sectors. Everything else is kept the same as in the GTAP-AGR model. This results in the production structures depicted in figure 3a-c.

Note that we use three of the six available production structures in LEITAP that are listed in the annex: plain production, fertilizer-land and feed-land. Also note that in the case of the fertilizer-land and feed-land production structures we only use part of the available tree, for example ignoring the possibility to substitute between high and low-protein feed or capital-energy substitutions.

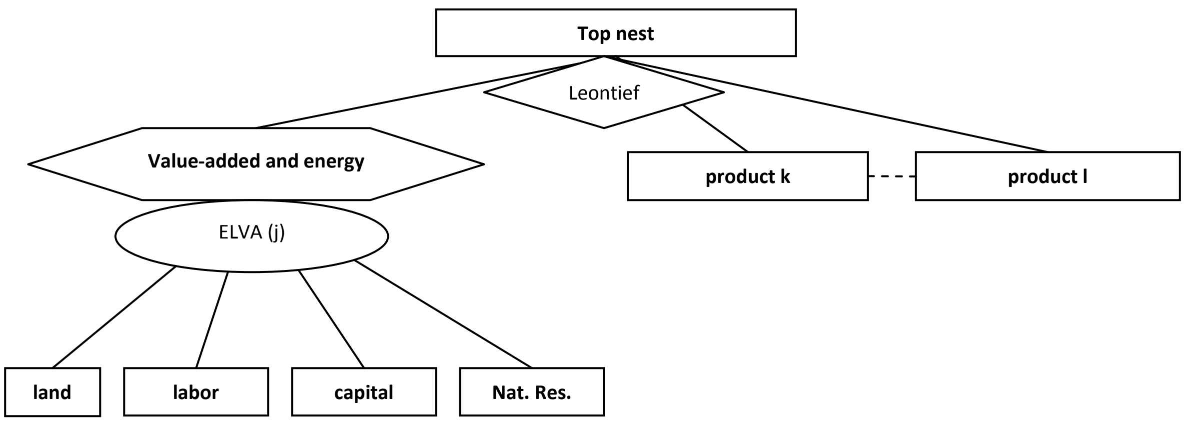


Figure 3a: Production structure for all sectors in GTAP set-up

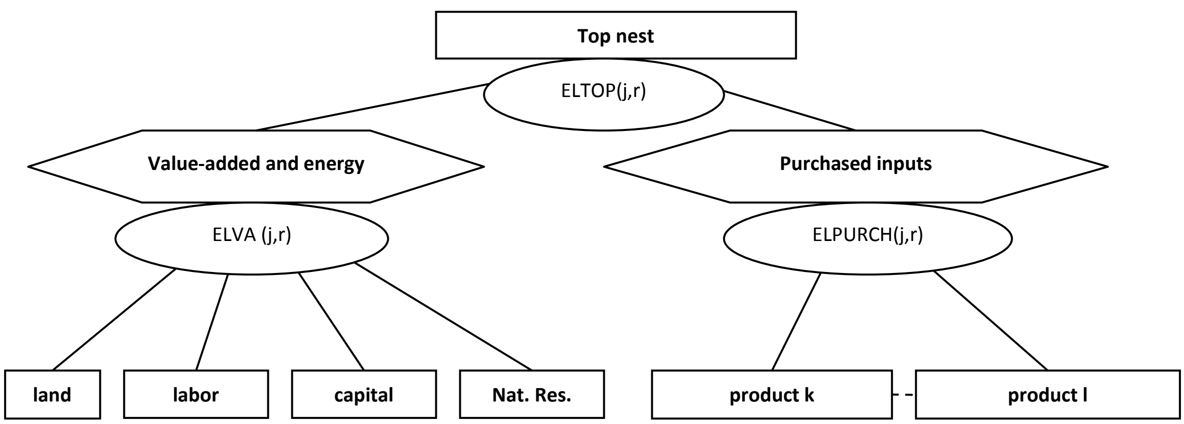
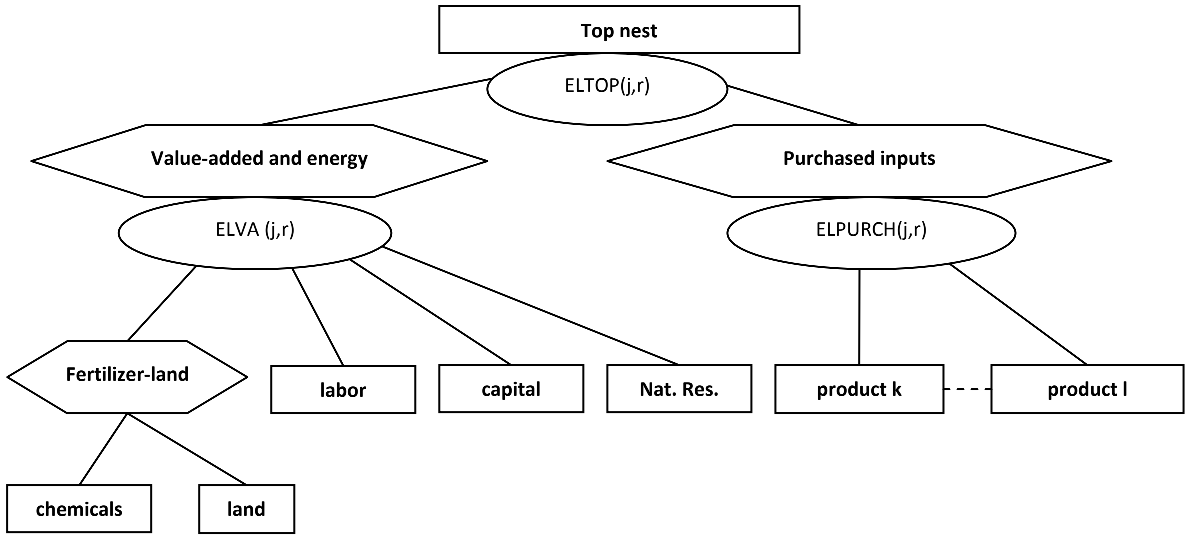


Figure 3b: Production structure for agricultural sectors in GTAP-AGR set-up

Note: non-agricultural sectors have a structure as in GTAP but with regional- and sector-specific elasticities of substitution in the value-added nest

Production structure for crop sectors in LEITAP set-up



Production structure for livestock sectors in LEITAP set-up

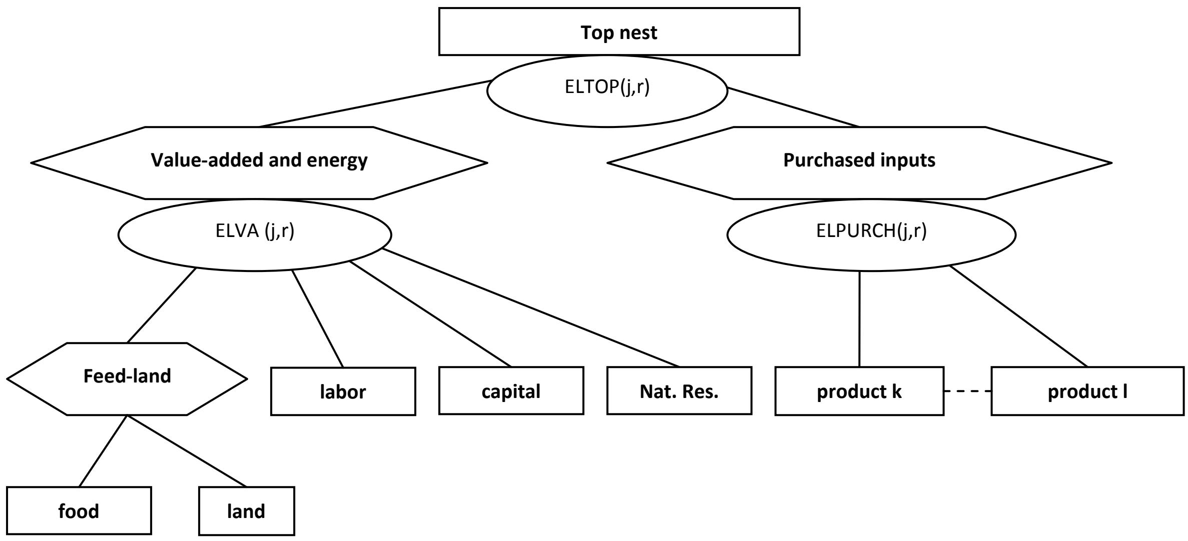


Figure 3c: Production structure for crop sectors in LEITAP set-up

Note: non-agricultural sectors have a structure as in GTAP-AGR (with regional- and sector-specific elasticities of substitution in the value-added nest)

Model – elasticities of substitution in production

For the GTAP model we use the standard GTAP elasticities of substitution: an elasticity of zero in the topnest and sector-specific elasticities in the value-added nest. In the GTAP-AGR model we use the GTAP-AGR elasticities that are both region- and sector-specific in the value-added nest for all sectors and which are non-zero in the topnest and intermediate input nest for agricultural sectors. For the LEITAP model we use the GTAP-AGR elasticities. Adding two more nests we also require two more elasticities one for fertilizer-land and one for feed-land substitution. Lacking empirical data we assume these elasticities to be 25% higher than the elasticities of the value-added nest, aiming at capturing better substitution possibilities between land and fertilizer or feed than with other factors of production. This implies that the elasticities in the fertilizer and feed nests are also region- and sector-specific.

Results

Since the modifications mostly affect agricultural production we focus our analysis on the impact of the decrease in international trade barriers by the implementation of a possible Doha agreement on agricultural production. We use the standard GTAP specification as the reference point in our analysis.

Baseline – world changes in production and endowment prices

We start with comparing the impact of the production structure on the baseline results, using the GTAP baseline as the reference point. Comparing the total production of all commodities for the world as a whole does not reveal any noticeable differences (table 3). If we zoom into primary agriculture, where the key changes to the production structure are made, we find growth rates to be about similar for GTAP-AGR and LEITAP which are both higher than for the GTAP specification. Digging a bit deeper into the results we find that for arable crops (for which we introduced the fertilizer-land interaction) and livestock (for which we introduce feed-land interaction) GTAP-AGR and LEITAP both again give similar and higher growth rates than GTAP. The increased substitution possibilities for factors of production in the GTAP-AGR specification thus permits higher growth rates. The additional substitution possibilities for land (a sluggish factor) in the LEITAP specification increases the growth rates a bit more, but the impact is limited compared to the higher substitution elasticities in the GTAP-AGR model. At the aggregate economy level the changes in agriculture are muted by manufacturing and service sectors.

Table 3: changes in total world production in the baseline scenario, for each model specification (% change)

	GTAP			GTAP_AGR			LEITAP		
	2004-2007	2007-2013	2013-2020	2004-2007	2007-2013	2013-2020	2004-2007	2007-2013	2013-2020
All commodities	12.1	13.1	28.3	12.1	13.1	28.3	12.1	13.1	28.3
Primary agriculture	12.6	16.2	27.2	12.9	16.8	28.5	12.9	16.8	28.6
Arable crops	12.5	17.1	27.0	12.8	17.7	28.4	12.8	17.8	28.6
Livestock	12.7	15.2	27.5	12.9	15.7	28.6	12.9	15.7	28.7

The GTAP-AGR and LEITAP specification both increase the substitution possibilities in the model. Having more substitution possibilities will dampen the price increases of inputs, which is obvious in the factor wages in table 4. In our simple baseline projection labor grows with the same rate as population and capital with the same rate as GDP, while there is no increase in the availability of land. In all three models the price of land thus increases more than the price of other endowments.

In the GTAP model there are no possibilities for substitution between value-added (including land) and intermediate inputs, and the substitution elasticity among primary factors in agriculture is (for the majority of regions) lower than for the GTAP-AGR and LEITAP models. Furthermore, the LEITAP model introduces additional substitution possibilities between land and fertilizer or feed. Given the huge increase in the price of land in the GTAP model these additional possibilities can be expected to affect further dampen the price increase of land. Comparing the price of land in the GTAP-AGR and LEITAP specification we find that the introduction of the feed and fertilizer-land nests lowers the price of land a bit more, but compared to the impact of switching to the GTAP-AGR specification the impact is limited.

Table 4: World change in prices of endowments (% change in market prices)

	GTAP			GTAP_AGR			LEITAP		
	2004-2007	2007-2013	2013-2020	2004-2007	2007-2013	2013-2020	2004-2007	2007-2013	2013-2020
Land	25.9	49.9	79.2	15.0	26.4	36.1	13.9	24.3	32.8
Unskilled labor	3.6	2.6	7.1	3.7	2.9	7.9	3.7	2.9	7.9
Skilled labor	3.0	1.4	6.0	3.1	1.7	6.7	3.1	1.7	6.7
Capital	-5.1	-5.0	-12.5	-5.1	-4.8	-11.8	-5.1	-4.7	-11.7

This raises the question what contributes most to the drop in land prices when switching to the GTAP-AGR specification: the higher elasticities in the value-added nest, the substitution possibilities between value-added and intermediates or the substitution possibilities among intermediates. To decompose these effects further we transform the GTAP model such that it has the substitution possibilities in the value-added nest while maintain the Leontief specification for intermediate inputs[5]. This results in price increases for land of 16.2, 28.7 and 40.0 percent for the three periods. The introduction of higher (and region-specific) elasticities of substitution in the value-added nest thus accounts for most of the dampening of the increase in price of land. The introduction of non-zero substitution elasticities for intermediate inputs dampens the price increase further. This impact is comparable in terms of size to introducing the fertilizer- and feed-land nests.

Baseline – regional changes in production and endowment prices

The pattern at world level is in line with the expected impact of introducing more substitution possibilities. When we disaggregate the results to the regional level we however find a more diverse range of responses with several instances of a lower production response in the GTAP-AGR and LEITAP models.

[5] These changes are implemented through changes in the model structure parameter meaning that we can rerun the GTAP baseline scenario with only a change in the model input parameter file. This allows for a quick decomposition of the impact of changing the substitution parameters.

Table 5: changes in regional production in the baseline scenario, for each model specification (% change in the 2013-2020 period)

	Primary agriculture			Arable crops			Livestock		
	GTAP	GTAP-AGR	LEITAP	GTAP	GTAP-AGR	LEITAP	GTAP	GTAP-AGR	LEITAP
EU-27	15.2	12.1	11.8	16.5	10.4	10.0	14.2	13.3	13.1
Europe & Russian Federation	22.5	22.3	22.2	22.0	20.6	20.4	22.9	23.5	23.5
NAFTA	18.1	18.4	18.2	16.5	16.0	15.6	19.0	19.7	19.6
Rest of America	22.5	24.8	25.1	21.1	23.6	23.9	24.2	26.4	26.6
Brazil	26.3	26.4	26.4	28.0	27.9	28.2	24.4	24.8	24.6
Oceania, Japan, Korea, Taiwan	16.9	13.8	13.4	13.2	9.6	9.3	21.5	19.1	18.6
China & Hong Kong	49.3	53.6	54.3	45.4	50.9	51.6	53.9	56.9	57.6
Rest of Asia	32.1	35.9	36.1	30.1	33.8	33.9	38.4	42.5	42.7
North Africa & Middle East	31.2	33.6	33.7	30.4	32.4	32.5	32.2	35.1	35.1
Sub-Saharan Africa	33.7	38.0	38.5	30.6	36.5	37.0	41.1	41.8	42.1
World	*27.2*	*28.5*	*28.6*	*27.0*	*28.4*	*28.6*	*27.5*	*28.6*	*28.7*

Note: instances where GTAP-AGR or LEITAP do not yield a higher growth rate (i.e. a pattern diverging from the pattern at world level) are highlighted in grey

Table 6: Changes in regional factor wages in the baseline scenario, for each model specification (% change in the 2013-2020 period)

	Unskilled labor			Skilled labor			Capital		
	GTAP	GTAP-AGR	LEITAP	GTAP	GTAP-AGR	LEITAP	GTAP	GTAP-AGR	LEITAP
EU-27	4.6	5.0	5.0	4.8	5.4	5.4	-8.8	-8.3	-8.3
Europe & Russian Federation	15.3	15.6	15.6	15.7	16.1	16.1	-11.8	-11.4	-11.4
NAFTA	1.8	2.5	2.5	1.9	2.5	2.6	-10.1	-9.5	-9.4
Rest of America	6.2	6.6	6.7	6.7	7.1	7.2	-12.8	-12.5	-12.5
Brazil	9.6	10.3	10.4	10.0	10.7	10.7	-11.1	-10.5	-10.4
Oceania, Japan, Korea, Taiwan	9.8	10.2	10.3	9.9	10.4	10.4	-8.7	-8.2	-8.2
China & Hong Kong	29.0	31.9	32.1	29.2	32.3	32.6	-19.2	-17.3	-17.1
Rest of Asia	14.7	17.3	17.3	16.2	18.5	18.6	-17.1	-15.4	-15.3
North Africa & Middle East	7.3	6.2	6.2	7.9	6.5	6.5	-14.2	-16.2	-16.2
Sub-Saharan Africa	4.0	4.4	4.4	5.6	5.2	5.2	-14.2	-14.9	-14.9
World	7.1	7.9	7.9	6.0	6.7	6.7	-12.5	-11.8	-11.7

Note: for land in all regions the GTAP model results in higher prices than the other two models, these data are therefore not reported; instances where GTAP-AGR or LEITAP do not higher returns to labor or a lower decrease in capital returns (i.e. a pattern diverging from the pattern at world level) are highlighted in grey.

Turning to factor returns (table 6) we find a more consistent pattern. In all regions the returns to land increase much less in the GTAP-AGR and LEITAP models, due to the increased substitutability of land. Since no region diverts from the global patter n these results are not reported. For the other main inputs in agricultural production, labor and capital, we find only for the African regions a divergence. Prices of labor decrease when the substitutability among factors of production is increased. A decrease in wages points towards a growth in the labor endowment outpacing technical change. The macros hocks confirm that these two regions have high rates of population growth (10.3 percent for North Africa and 16.8 percent for Sub-Saharan Africa). The high population growth coupled with the increased possibility to substitute among factors of production lowers the returns to labor relative to the GTAP model. An increase in wages does remain. The increased substitutability possibilities of factors also explains the stronger decline in capital returns compared to the GTAP model, increased substitution of labor for capital reduces the demand for capital and thus its price.

Doha scenario – world changes in production and endowment prices

When we analyze the impact of the Doha scenario we compare the results of each model to its own model to avoid compounding the effect of different baseline and Doha scenario results. We first take a global perspective, assessing the change in production in each of the three models (table 7). WE highlighted the instances where the GTAP-AGR results differ from the GTAP model, or where the LEITAP model differs from the GTAP-AGR model.

Table 7: Changes in production with a Doha agreement, for each model specification (% change compared to model-specific baseline in the 2013-2020 period)

	GTAP	*GTAP-AGR*	*LEITAP*
Paddy and processed rice	-1.6	-1.5	-1.5
Wheat	-0.5	-0.6	-0.6
Cereal grains not wheat	-0.2	-0.1	-0.1
Oil seeds	-2.1	-1.9	-1.9
Sugar cane and beet, sugar	-3.1	-2.9	-2.8
Vegetables, fruits, nuts	-0.3	-0.3	-0.3
Other crops	-0.6	-0.8	-0.8
Cattle, sheep, goats, horses	-1.6	-1.5	-1.5
Animal products nec	0.2	0.2	0.2
Raw milk	0.1	0.1	0.1
Dairy products	-0.2	-0.3	-0.3
Sugar	-3.1	-3.0	-3.0
Vegetable oils and fats	0.0	-0.1	-0.1
Food nec mainly compound feed	0.1	0.1	0.1
Other agro-food products	0.1	0.1	0.1
Forestry	0.0	0.0	0.0
Fosil energy sectors	-0.1	-0.1	-0.1
Chemical, rubber,plastic prods	-0.3	-0.3	-0.3
Industry	0.1	0.1	0.1
Services	0.1	0.1	0.1

Note: sectors with a different response in the GTAP-AGR or LEITAP model are highlighted in grey.

The main observation is that when we compare the results to the own baseline of each model there are no significant differences in the expected impact of a Doha agreement from a global perspective.

As to be expected since we modified the agricultural production structure, the minor differences are found in either the primary of processed agricultural sectors. There is no clear pattern in the direction of the difference, sectors decrease either less or more when the substitutability of factors of production is increased in the GTAP-AGR. There only instance where the LEITAP model has a slightly different result from the GTAP-AGR model is in the case of sugar cane. This is a highly protected sector suggesting that differences between the models will only come to the fore with profound shocks.

Given the increased substitution possibilities in the GTAP-AGR and LEITAP models we expect less change in the factors of production than in the GTAP model. Table 8 summarizes changes in endowment prices from a global perspective. The only visible difference is in the price of land which drops less in the GTAP-AGR model. Introducing the feed and fertilizer-land substitution possibilities in the LEITAP model is not reflected in the land price at global level. The main difference between land and the other factors is that land is sluggish, i.e. cannot adjust freely when relative prices change. The increased substitution possibilities in the GTAP-AGR model partly reverse this sluggishness, resulting in a more modest change in land.

Table 7: Changes in factor wages with a Doha agreement, for each model specification (% change compared to model-specific baseline in the 2013-2020 period)

	GTAP	*GTAP-AGR*	*LEITAP*
Land	-1.9	-1.4	-1.4
Unskilled labor	0.0	0.0	0.0
Skilled labor	-0.1	-0.1	-0.1
Capital	0.1	0.1	0.1

Note: sectors with a different response in the GTAP-AGR or LEITAP model are highlighted in grey.

We have only adjusted the substitution elasticities in the agricultural sector which explains the absence of a noticeable effect on labor and capital. These are mobile factors and the impact of the non-agricultural sectors which do not vary among the model versions (see table 6) dominate any changes that may occur due to a different specification of agricultural production.

Doha scenario – regional changes in production and endowment prices

The global perspective above may obscure variations among regions. Analysis of regional differences in production response in each of the models results in a rather varied picture. As an illustration figure 4 shows the regional changes in wheat production next to the change at world level. It is immediately obvious that the rather modest differences at world level are due to rather different but opposite effects at regional level. For example, for China the increase in production in the GTAP model is more modest than in the other two models whereas for the EU the increase in the GTAP model is stronger than for the other two models. The impact of moving from a GTAP-AGR to a LEITAP specification of agricultural production has a consistent impact in the sense that the pattern of change of the GTAP-AGR model is further enhanced (either further lowering or further increasing the production response).

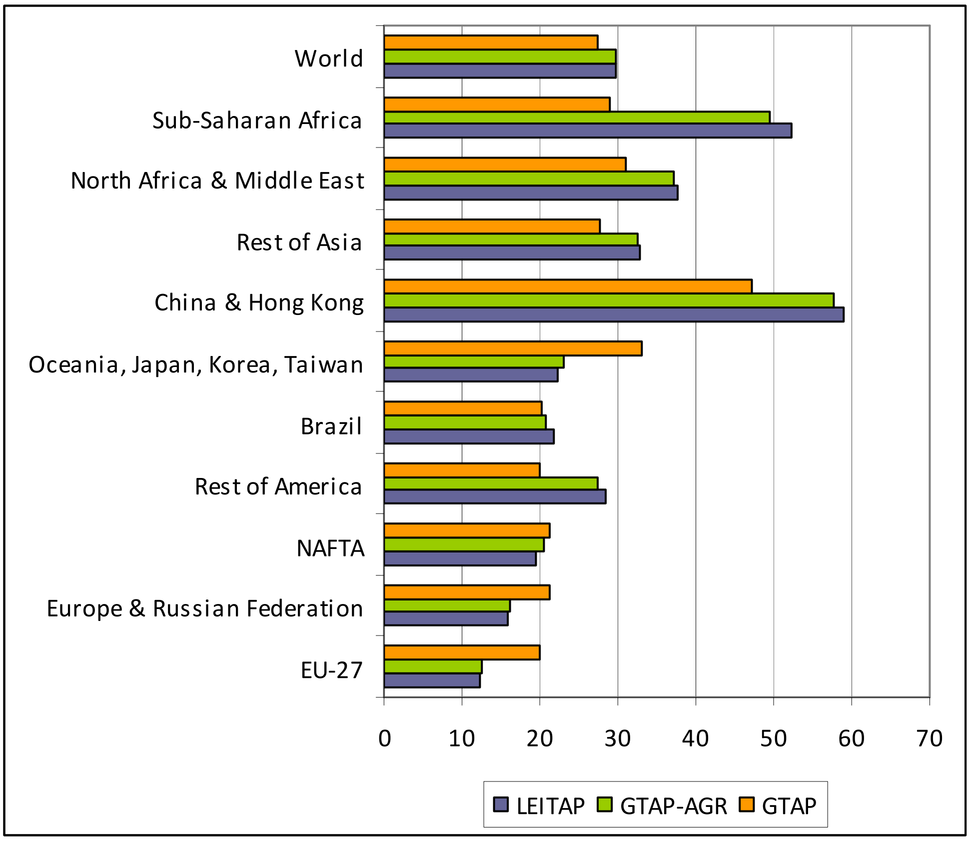


Figure 4: Changes in production of wheat with a Doha agreement, for each model (% change wrt own baseline of each model, 2013-2020 period)

The changes in the price of land can be taken as a kind of summary indicator of the changes in agriculture (the only sector using land in production). Figure 5 presents the changes in the price of land by region. Again the change in price of land at the global level hides a rather varied picture at the regional level. There are regions with a decline in the price of land like the EU which is due to high initial levels of protection for agriculture. Other regions with lower initial levels of protection, like Brazil, experience an increasing demand for agricultural land. Comparing the results across models we find for most regions the expected strongest response for the GTAP model and a considerable lower response for the GTAP-AGR and LEITAP models. Again the main cause of the difference is the increase in region-specific substitution elasticities in the value-added nest. The additional feed- and fertilizer land nest only reduce the land response with modest amount.

Again however the results show that regions may behave differently. Cases in point are the Oceania region (including Australia, New Zealand, Japan, Korea and Taiwan) where the price drop in the GTAP-AGR model exceeds the response in both the GTAP and LEITAP model, and Brazil where the increase in land prices in the GTAP-AGR model exceed the other two models. Since the addition of the feed- and fertilizer nests in the LEITAP model dampens the response of the land price again the cause may be the intermediate input use shares in these two regions.

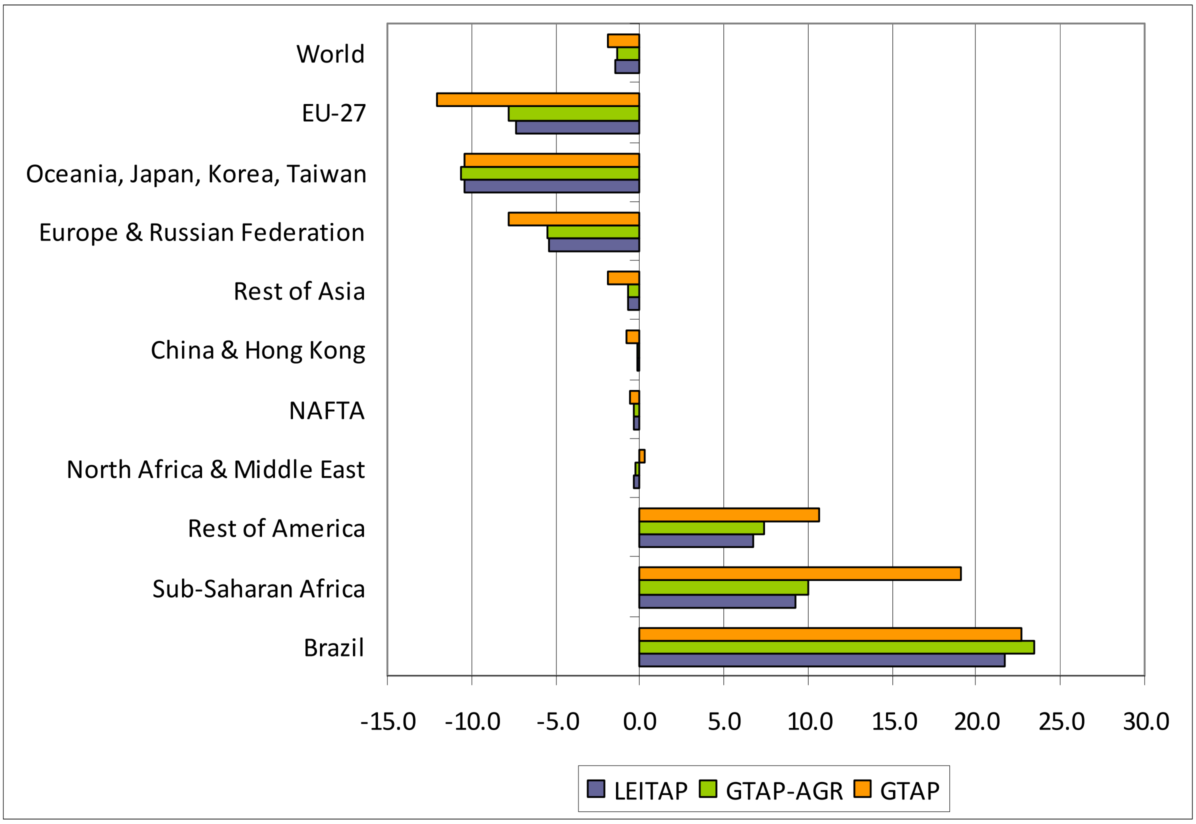


Figure 5: Changes in the price of land with a Doha agreement, for each model (% change wrt own baseline of each model, 2013-2020 period)

Conclusions

The restructuring of the LEITAP model is a major investment. Although the work has not yet finished the benefits are already visible. An internal training program for new modeling staff uses the new system using plain vanilla GTAP settings to make both the model as well as the modeling software and procedures used at LEI accessible. The modular set-up of the model makes through the GTREE software makes the code more accessible to new users, extensions of the GTAP model that characterize LEITAP are immediately visible in the code. An additional benefit of having the code divided in many small text files is that the usefulness of the version control system is increased, changes to the code can be precisely tracked to a few files which adds the development of the model by a team of modelers.

When testing the effect of changes in eth production structure the benefits of the flexible set-up with sets provided invaluable. When the errors appeared related to the gas sector in China a setting the model to plain vanilla GTAP showed that the likely cause was in eth data not the extensions in LEITAP. Since the sector was not essential for the current testing the flexible set-up allowed quick generation of a new model with an aggregated fuel sector which solved the problem (at least in modeling terms).

The flexible set-up also helped in determining the sources of variations between models. For example running a GTAP-AGR with only the new value-added substation elasticities implemented, while maintaining the Leontief function in the top- and intermediate nests. Similarly the impact of introducing feed- and fertilizer nests in the LEITAP model was decomposed by also running a model with only a fertilizer nest. With the generation of a new model within a few minutes these kind of decompositions to better understand the workings of the model become feasible.

When we tested the model using the Doha scenario the flexibility offered by the set-driven specification allowed us to focus this first round of testing on a simple extension with just two nests for feed- and fertilizer interactions. In terms of impact the results were more varied that expected. Although overall the increased substitution possibilities rendered the expected responses some regions diverted from the overall pattern. This highlights the importance of the initial data or the chosen aggregation on model results. Once cannot a priori determine the impact of a model extension on results which again makes the modular set-up of the model a great benefit for modeling work. One can quickly assess for a specific application the merits of each extension and adjust the model and/or data accordingly.

The application described here is a first test of the restructured model. In the internal training program the model is used with about eight different aggregations to reflect the interests of each of the researchers involved. The extensions that characterize LEITAP will be tested in these different aggregations in the course of the training program which will provide an indication of the robustness of results to model specification and data.

Annex 1: Available production structures

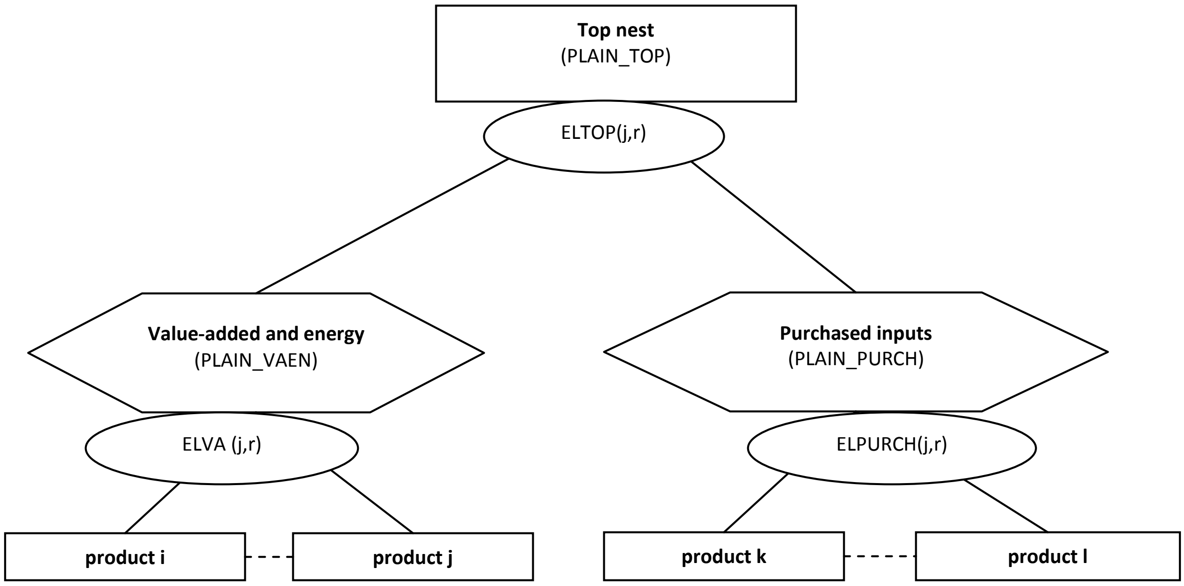


Figure A.1: Production tree for sectors with plain production (PROD_PLAIN) in regions with an extended production structure (N_REG)

Note: in brackets is the set name for the products entering in that nest

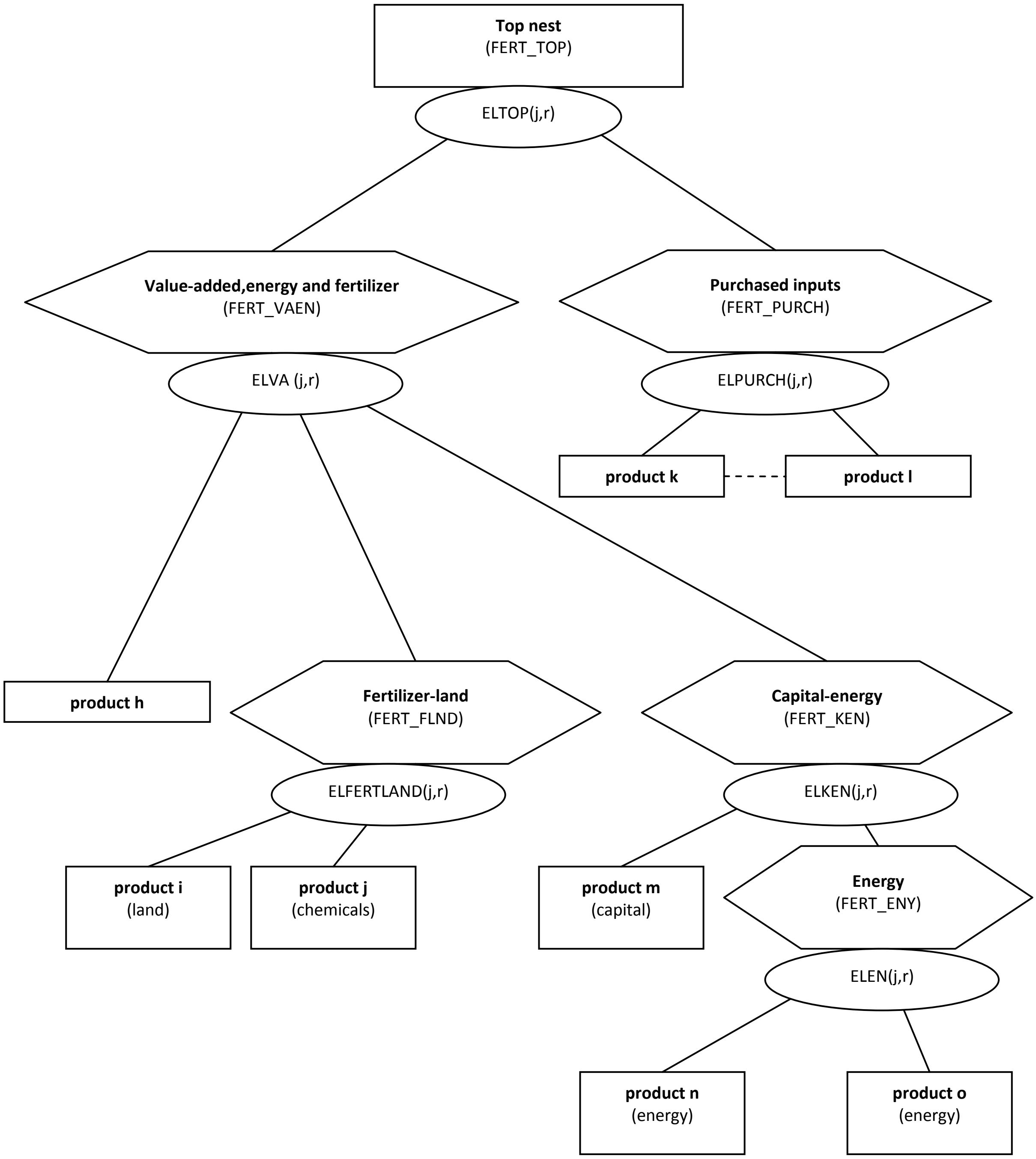


Figure A.2: Production tree for sectors with fertilizer-land interaction (PROD_FERT) in regions with an extended production structure (N_REG)

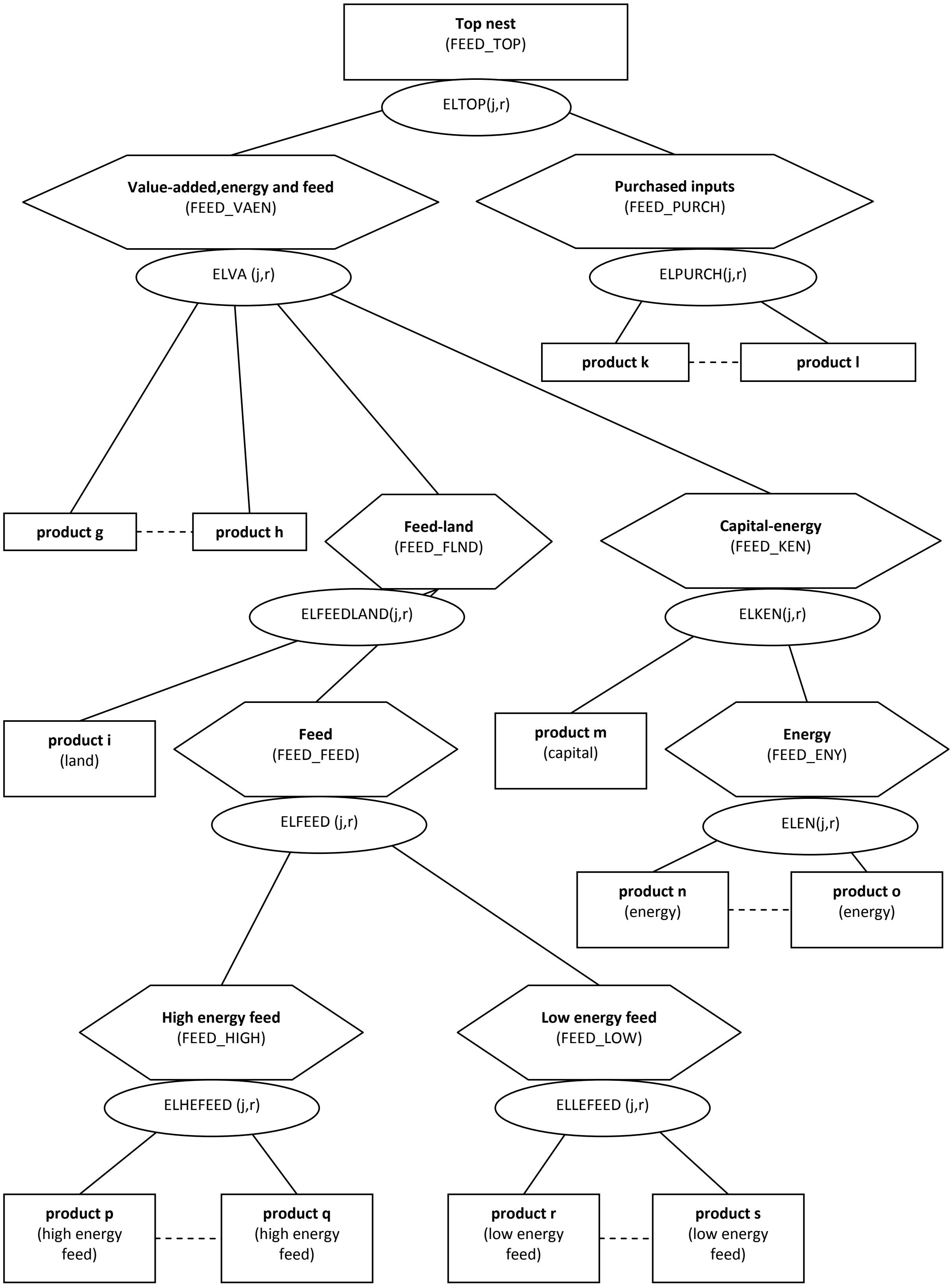


Figure A.3: Production tree for sectors with feed-land interaction (PROD_FEED) in regions with an extended production structure (N_REG)

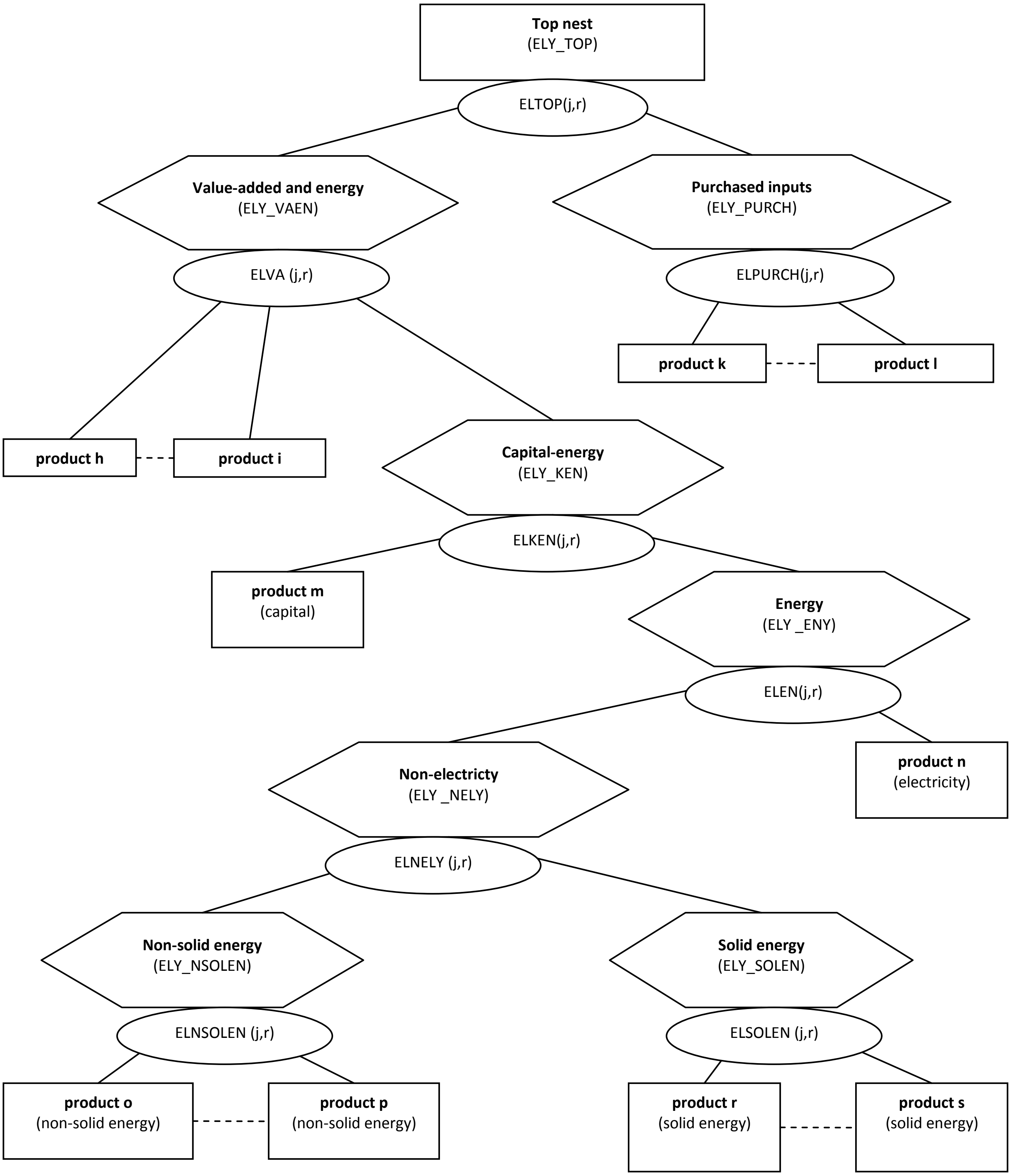


Figure A.4: Production tree for electricity sectors (PROD_ELY) in regions with an extended production structure (N_REG)

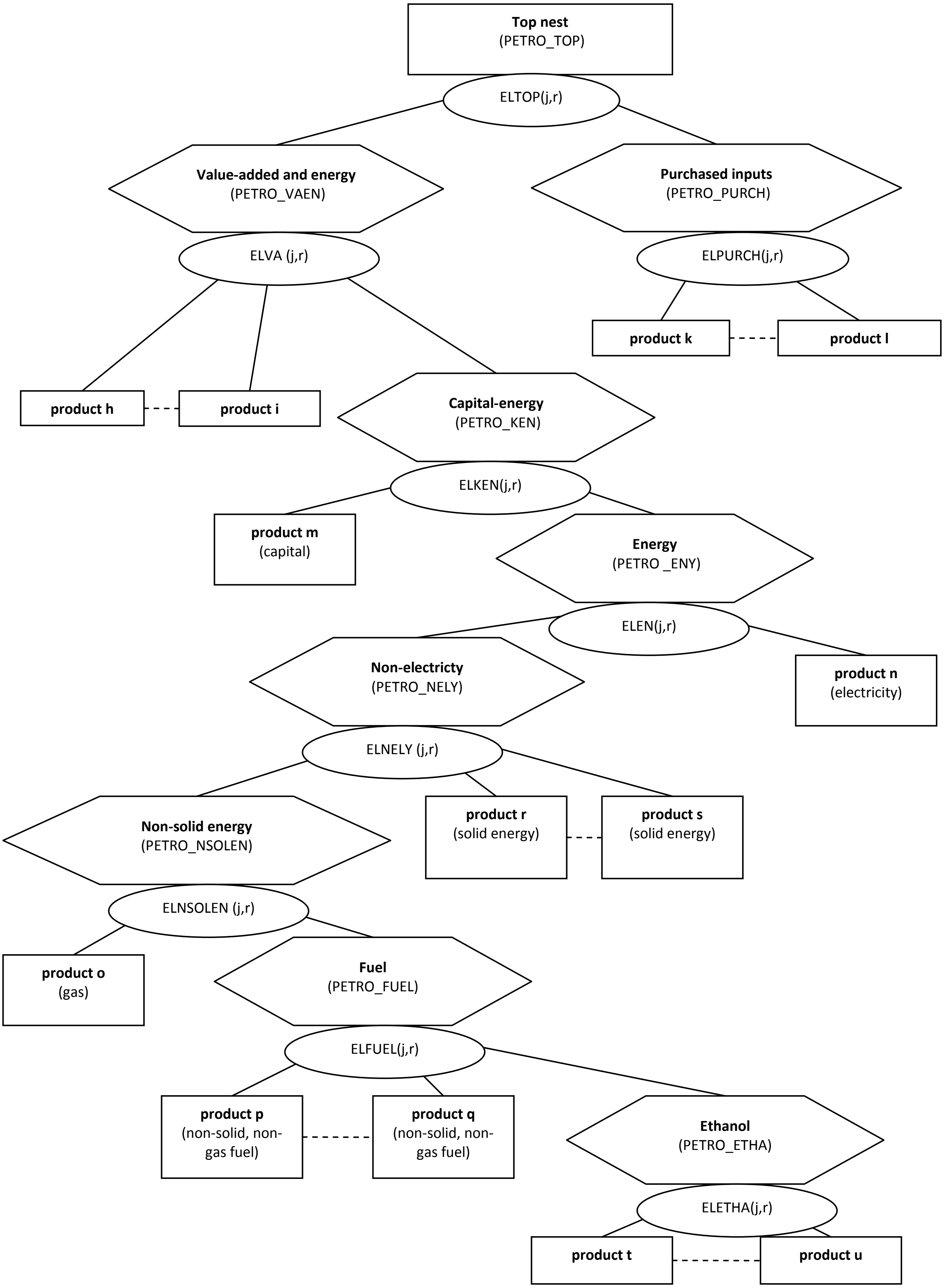


Figure A.5: Production tree for petroleum sectors (PROD_PETRO) in regions with an extended production structure (N_REG)

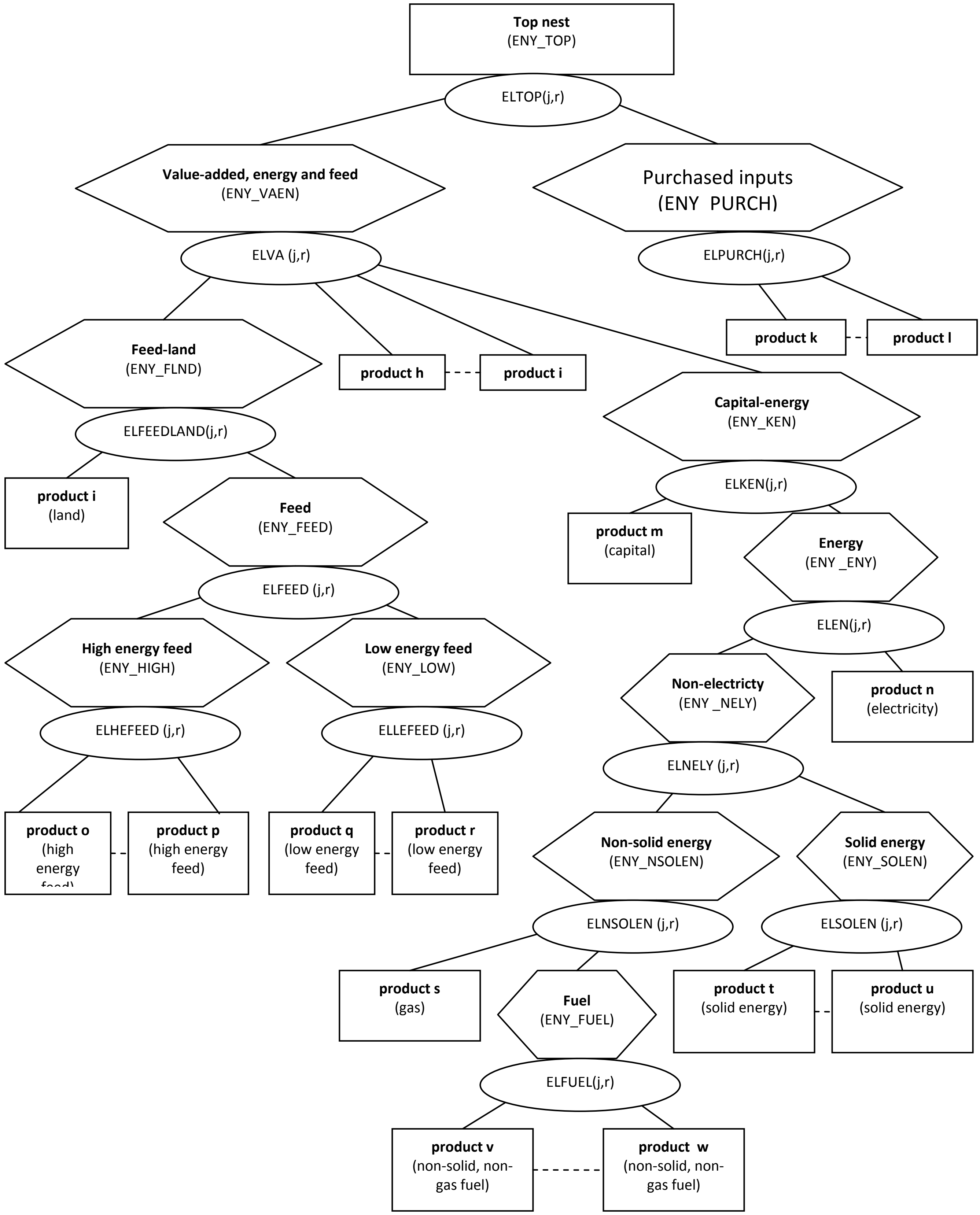


Figure A.6: Production tree for energy substitution (PROD_ENY) in regions with an extended production structure (N_REG)