European Commission

JRC TECHNICAL REPORTS

Model linkage between CAPRI and MAGNET: An exploratory assessment

George Philippidis
John Helming
Andrzej Tabeau

2017

Joint Research Centre

EUR 28625 EN

Contact information
Name: Robert M'Barek
Address: Calle Inca Garcilasso, 3 Edificio Expo 41092 Seville Spain
E-mail: Robert.M'BAREK@ec.europa.eu
Tel.:+34 954 488489

JRC Science Hub
https://ec.europa.eu/jrc

JRC106595

EUR 28625 EN

PDF ISBN 978-92-79-69101-0 ISSN 1831-9424 doi:10.2760/712139

Luxembourg: Publications Office of the European Union, 2017

How to cite this report: Philippidis, G., Helming, J., Tabeau, A., *Model linkage between CAPRI and MAGNET: An exploratory assessment*, EUR 28625 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-69101-0, doi:10.2760/712139, JRC106595

Table of Contents

Acknowledgements

This report is part of the preparatory work of Scenar 2030, a study providing insight into the impact of different options of the Common Agricultural Policy at the horizon of 2030. It is part of the specific contract 154208.X20 "Scenar 2030: parameters and model chain preparation" implementing framework contract 154208-2014 A08-NL.

The authors would like to thank DG Agriculture and Rural Development for their support of this research. Thanks also go to Emanuele Ferrari and Robert M'barek (JRC.D4 Seville) who provided helpful comments on an earlier draft.

George Philippidis is currently with the Aragonese Agency for Research and Development (ARAID) and affiliated to Wageningen Economic Research (WEcR), Wageningen University (The work has been mainly carried out within the JRC since the author was at that time affiliated with the JRC); John Helming and Andrzej Tabeau are affiliated to WEcR.

1. Introduction, background and aims

It is well-known that partial equilibrium (PE) and computable general equilibrium (CGE) models have structural differences both in terms of the data and the behavioural elements (i.e., explicit or implicit elasticities), which can generate divergent results, whilst previous precedents in the literature even show that CGE and PE can generate contradictory findings for the same scenario.[1] Although this is well recognized within the modelling community, in the policy arena it can often be hard to reconcile the findings of both models when presenting a consistent story line for a given policy reform.

In the past, previous work commissioned by the Joint Research Centre (JRC), Seville, on behalf of DG Agri, forged a 'soft' model linkage (Helming et al., 2010; Nowicki et al, 2006, 2009), such that both models generate a mutually consistent storyline. Typically, a soft linkage is driven by a more *ad hoc* assessment of the overall results (i.e., are the models broadly telling the same story?), whilst one plays to the strengths of each model to serve as a source of input to the other. For example, the CGE model, with an explicit or endogenous treatment of factor markets, world trade and macro aggregates, could conceivably be used within a PE model. Similarly, the sectoral detail and econometric foundation in supply response which serves some PE models well could be employed to assess and improve the veracity of the CGE model results.

Under the auspices of project 154208-2014-A08-NL, entitled, "Scenar2030, parameters and model chain preparation", the Economic of Agriculture unit of the JRC requested a further look at this issue to better understand the merits of different model linkage options. More specifically, as part of technical specification for task 5 ('preparation of model chain'), two forms of model linkage, broadly labelled as 'soft' and 'hard' linkage are considered.

The advantage of the soft approach is that it is relatively straightforward to implement in terms of the necessary modelling modifications. On the other hand, the 'soft' approach adopted in the Scenar2020 project through linkage of variables was, as

[1] Conducting an impact analysis of the Uruguay Round, Anderson and Tyers (1988) predicted in their study that a fall in the economic welfare of the developing countries would follow liberalisation by industrialised nations due to the rise in international food prices, with consumer losses outweighing producer gains. The same scenario was conducted under CGE conditions (Burniaux and Waelbroeck, 1985; Loo and Tower, 1989) both of which showed welfare gains due to the effects of the non-agricultural sectors. Noting the reconciliation of the structural differences between the model approaches, Anderson and Tyers (1993) reverse their initial estimates from a sizeable loss (1985 US $14bn) into a significant gain (US $11bn).

noted above, implemented more on an *ad hoc* basis, rather than following a systematic framework. Thus, subject to the prejudices of the model scenario (i.e., the scenario design, the type of shocks etc.), the use of variable linkage could conceivably vary considerably. This, in turn, has led to the alternative choice of a 'hard' linkage which seeks to forge a union between the structural or behavioural elements of the model (see, for example, Britz and Hertel, 2011; Pelikan et al., 2015). Whilst this approach is intuitively appealing because it follows a very specific methodological approach, it requires considerably more modelling expertise to implement, whilst the potential robustness of the two models being linked is, at the current time, far from certain.[2] A fuller exposition of the hard linkage approach is given in section four below with some reflections of its potential suitability for advanced policy analysis using the MAGNET model.

For the purposes of the current (tentative experiments), in section two, a 'test bed' study is described, which considers a more systematic class of 'soft' model linkage between two well-known and respected models from the iMAP platform, namely, the Common Agricultural Policy Regionalised Impact (CAPRI) PE model and the Modular Applied GeNeral Equilibrium Tool (MAGNET) CGE model. In CAPRI, a standard CAP baseline is run, whilst in the MAGNET model, two specific experiments are implemented. The first runs a standard CAP baseline in the MAGNET model, whilst the second implements the same baseline shocks with the inclusion of model predictions of output taken from CAPRI. The aim of the exercise is simply to ascertain the extent to which the MAGNET model results (section three) diverge between the two experiments and assess the degree of compromise required in MAGNET to accommodate said changes.

Clearly, if considerable divergences are found, and one considers that the CAPRI sectoral output results are superior, then this could potentially warrant the need for a more extensive research effort to provide a systematic, theoretically consistent and scientifically rigorous approach to model linkage for future policy impact assessments.

2. Model descriptors and experimental design

[2] Within the two cited studies, the policy shocks were very discrete, whilst a more aggressive set of policy shocks (i.e., projections etc.) which are typically used to characterise policy outlooks have, hitherto, not been attempted.

2.1 CAPRI model – brief description

CAPRI is an EU-27 partial equilibrium model for the agricultural sector at NUTS2 level (aggregated regional farm approach). It consists of a supply module and a global market model. The supply module of CAPRI comprises around 280 regional farm models (one farm model for each NUTS2 region in the EU27, Norway, Western Balkans and Turkey) covering about 50 crop and animal activities for each of the regions and including about 50 inputs and outputs[3]. The objective function of the regional farm model optimizes regional agricultural income (gross margin) at given prices and subsidies, subject to constraints on land, policy variables, feed and plant nutrient requirements in each region. A land supply curve allows land use area to increase and contract as a function of the marginal returns to land. An interesting feature of the supply module of CAPRI is that agricultural activities are divided into an extensive (low input, low yield) and an intensive type (high input, high yield).

The gross margin is the total revenue including sale incomes from agricultural products and detailed EU CAP payments to farmers (coupled and decoupled payments) minus the accounting variable costs of production activities. The accounting costs include costs of seeds, fertilizers, crop protection, feeding and other specific costs. A quadratic cost function per activity per region is introduced in the above mentioned objective function to calibrate the regional farm model to the observed situation. This quadratic cost function is designed to capture the effects of factors that are not explicitly included in the model such as price expectation, risk aversion, labour requirements, and capital constraints (Heckelei, 2002). Parameterisation of the crop and region specific quadratic costs functions is partly[4] realised via econometric estimation (Jansson and Heckelei, 2011). For the remaining activities supply elasticity information is used.

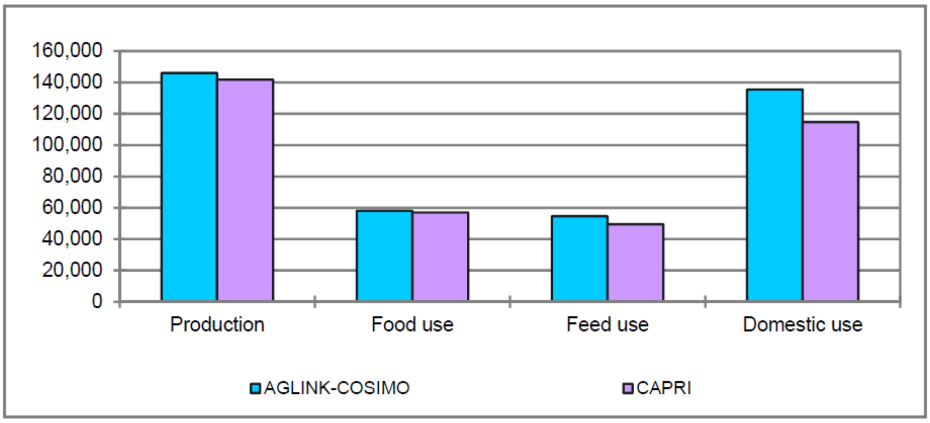
To include the feed-back effects from the market, the supply module is linked to a market module. The CAPRI global market model is a comparative static multi-commodity model. It covers 47 primary and secondary agricultural products. The supply module and the global market model of CAPRI are iteratively linked, to model the interaction between supply behaviour and price changes. Equilibrium ensures that all agricultural input- and output-markets clear (Britz and Witzke (eds.), 2014).

[3] A further disaggregation to ten farm types for each region (in total 2,450 farm-regional models, EU27) is also possible. This feature of CAPRI is however not used for the application in this paper.

[4] Not all NUTSII regions are included in the econometric estimation.

The CAPRI baseline is calibrated to the AGLINK-COSIMO baseline. The different steps needed to calibrate both the supply and market module are described in detail in Himics et al. (2014). Compared to AGLINK-COSIMO, CAPRI is more detailed in regional coverage, agricultural production activities, cost components etc. As a result, more interactions between model agents and more micro- and macroeconomic constraints (cost allocation, nutrient balances, policy variables) need to be considered during the calibration (Himics et al., 2014). Owing to these additional layers of detail, the CAPRI baseline will not exactly replicate AGLINK-COSIMO. For example, in the case of the wheat market, these subtle differences are highlighted in Figure 1.

Figure 1: CAPRI and AGLINK-COSIMO baselines for wheat balances in the EU-27.



Source: Himics et al., 2014

2.2 MAGNET model – brief description

The MAGNET model, fully documented in Woltjer and Kuiper (2014), is an advanced variant of the well-known multi-regional neoclassical Global Trade Analysis Project (GTAP) model (Hertel, 1997) and database (Narayanan et al., 2015). The GTAP data fuses a series of input-output tables for 140 countries/regions and 57 tradables (including agriculture, food, manufacturing, services, natural resources and energy), with gross bilateral trade, transport and trade policy data (i.e., *ad valorem* applied tariffs). In each region, both the data and the model accounting conventions ensure that the standard Keynesian macro balances are observed (i.e., zero balance of payments). The behavioural equations employ standard assumptions of neoclassical constrained optimisation, constant returns to scale technologies and perfect competition, whilst a series of market clearing equations are imposed to ensure that supply equals demand.

The MAGNET model builds on this foundation by including state-of-the-art modelling code from the latest developments in the literature, as well as significant data developments to include new or emerging industries which are not included within the standard classification of the national input-output accounts. Given its modular structure, MAGNET affords the user the flexibility to choose from a list of non-standard modules which are most pertinent to the study at hand.

The focus here is on agricultural market developments. Thus, a full representation of agricultural and food sectors is chosen, whilst the study also takes advantage of further data sector splits to include biomass usage in energy and feed. The model explicitly treats the specificities of agricultural factor and input markets to cater for input substitution possibilities, heterogeneous land transfer and relative wage differentials between agricultural and non-agricultural labour and capital. In addition, the model captures changes in the pattern of agri-food demand elasticities over time resulting from structural economic change (Woltjer and Kuiper, 2014). A Leontief joint production technology is assumed in forestry and agricultural sectors to model residue by-products, whilst the same modelling technique is used to treat oilcake and distiller's dried grains with soluble (*DDGS*) feeds by-products from first generation bio-diesel and bio-ethanol sectors. Finally, an additional module (Boulanger and Philippidis, 2015) characterizes a CAP baseline which is used as a basis for the scenario design in the model.

2.3 Experimental design

In an attempt to harmonise as much as possible the baselines of the two models, a number of modelling assumptions are implemented. First, the benchmark year for the current MAGNET model is 2007,[5] which is comparable with the starting point of our CAPRI baseline (2007/8/9) average. Secondly, since the CAPRI baseline is based on a comparative static framework, then the MAGNET model is also converted to such a format (as opposed to its recursive dynamic option).[6] Furthermore, since for the baseline the CAPRI market model is among others calibrated to AGLINK-COSIMO

[5] This benchmark year will be changing to 2011 to reflect the latest release of the GTAP database (version 9).

[6] This simplifies the analysis considerably since one does not have to make *ad hoc* assumptions regarding the distribution of CAPRI baseline shocks (i.e., front-loaded, back-loaded, time-linear) across multiple periods in the MAGNET model.

(Himics et al., 2014), it serves as a superior point of reference (vis-à-vis MAGNET) for accurately gauging potential developments in agricultural markets over medium to longer term time horizons.

Thus, to examine the performance of the 'standard' MAGNET model predictions, in a second MAGNET simulation, agri-food output predictions in the CAPRI model baseline are directly implemented by performing a closure swap with a Hicks neutral output productivity variable, whilst sectoral prices are allowed to continue adjusting endogenously.[7]

Figure 2: Comparative static experimental design

MAGNET Simulation A: Standard MAGNET CAP baseline between 2007-2020 substituting MAGNET projections of GDP and population with those of the CAPRI model

vs.

MAGNET Simulation B: Experiment A plus agri-food outputs in the MAGNET model are shocked (via closure swap) to mimic CAPRI predictions. In the EU27 regions, output linkage is in thirteen agri-food sectors. In Non-EU regions, output linkage is restricted to five food sectors (see section 3)

Table 1 shows the sectoral aggregation employed in MAGNET (sector abbreviations used here are in inverted commas). To ensure compatibility between CAPRI and MAGNET output changes, additional code in the CAPRI model is inserted such that the agro-food sectoral concordance (where possible) between the two models is equivalent (Table 1 – CAPRI commodities are inside the brackets), thereby facilitating the direct transfer of CAPRI output results to MAGNET. To further harmonise the two models, the regional aggregation (Table 1), which covers the main players on agri-food world markets, is also the same in both models.

Table 1: CAPRI and MAGNET sectoral and regional aggregation

Agri-Food sectors (where linked, CAPRI commodity concordance in brackets)
Primary agriculture (10 commodities): wheat – 'wht' (soft wheat, durum wheat); other grains – 'gro' (rye, barley, oats, maize, other cereals); oilseeds – 'oils' (rape, sunflower, soya, olive oil, other oils); raw sugar – 'sug' (n.a.); vegetables, fruits and nuts – 'hort' (tomatoes, other vegetables, apples, other fruit, citrus, table grapes, table wine, other wine); other crops – 'ocr' (pulses, potatoes, tobacco, other industrial crops, nursery, flowers, other crops); pigs and poultry – 'oap' (eggs); raw milk – 'rmk' (milk);
Food and beverages (9 commodities): red meat – 'cmt' (beef, sheep and goat meat); white meat- 'omt' (pork, poultry meat); dairy – 'milk' (butter, skimmed milk powder, cheese, fresh milk, cream, concentrated milk, whole milk powder, whey

[7] In a CGE model, it is not possible to fix quantities and prices simultaneously. The chosen closure approach respects the equilibrium conditions of the model, whilst it implicitly calibrates output productivity effects over time to 'forecasted' output changes in the CAPRI model.

powder, caseine); sugar processing – ‘sugar’ (sugar); vegetable oils and fats – ‘vol’ (rape oil, sunflower oil, soya oil, olive oil, other oil); processed rice – ‘pcr’ (rice)
Agri-Food sectors (non linked): paddy rice – ‘pdr’ ; sugar cane/beet – ‘c_b’ cattle and sheep – ‘ctl’ ; other food processing – ‘ofd’.

Regional disaggregation (23 regions):
EU15 (old EU members); EU10 (2004 accession members); BULROM (Bulgaria and Romania); WBA (Western Balkans); REU (Rest of the EU); TUR (Turkey); RUSPlus (Russia plus old Russian replublics); MIDEAST (Middle East), CHN (China), JPN (japan); INDO (Indonesia); KOR (South Korea); INDPAK (India and Pakistan); RoASIA (Rest of Asia); USA (United States of America); CAN (Canada); MEX (Mexico); ARG (Argentina); BRA (Brazil); RoSA (Rest of Latin America); NAFR (North Africa); SSA (Sub-Saharan Africa); ANZ (Australia and New Zealand).

As a key driver of the model results, the macro projections in each of the models differ. To remove this bias when comparing different sets of MAGNET results (i.e., with- and without linkage to CAPRI), a common set of macro drivers is used in both models. Since the output results from CAPRI are fed into MAGNET, for the purposes of consistency, it is therefore logical to also input the real GDP and population shocks (Table 2) from CAPRI into MAGNET. The chosen period is between 2007 and 2020 since this is the time horizon in MAGNET’s CAP baseline which characterizes the two financial frameworks 2007-13, 2013-2020, for which policy data are available. In MAGNET, skilled and unskilled labour endowments mimic the change in population (i.e., fixed employment rates), capital shocks follow changes in real GDP (fixed medium to long-run capital-output ratio), whilst natural resources are assumed to grow at one-quarter the rate of the change in the capital stock. The model closure in MAGNET is typically neoclassical, where trade and capital account balances sum to zero in each region.

Table 2: CAPRI baseline shocks to real GDP and Population.

	2007-2020 Real GDP	2007-2020 Population		2007-2020 Real GDP	2007-2020 Population
EU15	11.4	8.4	**INDPAK**	125.7	16.1
EU10	31.7	-0.6	**RoASIA**	76.7	15.5
BULROM	31.4	-8.1	**USA**	38.6	10.0
WBA	37.5	-1.0	**CAN**	31.4	14.1
REU	24.6	7.6	**MEX**	55.4	14.8
TUR	61.1	27.0	**ARG**	68.3	10.5
RUSPlus	69.0	2.4	**BRA**	64.6	10.1
MIDEAST	66.1	26.2	**RoSA**	68.3	15.9
CHN	200.7	6.6	**NAFR**	66.1	19.7
JPN	20.7	-2.3	**SSA**	88.6	33.5
INDO	95.4	15.0	**ANZ**	44.6	16.7
KOR	59.6	6.1			

3. Results

The following section provides a discussion of the MAGNET model results in the non-linked and linked scenarios. It should be noted that initial attempts to implement a wholesale linkage of all CAPRI output predictions within the MAGNET model were met with implausible percentage changes (i.e., greater than 100% falls) in prices and quantities, whilst the *walraslack* figure was unacceptable.[8] Thus, undertaking a series of simulation runs, a final version was generated where (i) CAPRI output changes for red and white meat, dairy, processed sugar and vegetable oils and fats are imposed in all non-EU regions, allowing 'upstream' agricultural activities in these regions to adjust endogenously; and (ii) in the EU regions, all available CAPRI predictions are implemented.[9]

3.1 Output

Tables 1 and 2 show MAGNET's sectoral agri-food output results under simulations A (no CAPRI link) and B (CAPRI link). Given the differences in data construction, model structure and behavioural elasticities in the CAPRI and MAGNET models, it is not plausible to expect a close convergence between the magnitudes of the model results. Instead, the approach taken here is to gauge the coherence of the MAGNET model results in terms of the predicted signs.

Table 3: EU region production changes (%) with and without link to CAPRI

	Simulation A			Simulation B		
	NO LINK	**NO LINK**	**NO LINK**	**WITH LINK**	**WITH LINK**	**WITH LINK**
	EU15	**EU10**	**BULROM**	**EU15**	**EU10**	**BULROM**
pdr	-14,9	21,7	9,0	-18,1	35,0	2,4
wht	-3,1	26,5	9,9	-1,9	10,4	21,7
gro	-1,0	14,4	3,2	-5,1	6,7	42,7
oils	-18,1	29,0	26,8	5,4	12,2	61,1
sug	-7,2	-1,6	-11,9	-10,7	-11,1	-23,5
hort	1,1	25,6	7,3	0,9	-5,5	-5,1
ocr	3,6	23,1	8,4	-4,3	-48,5	-12,7
ctl	-9,8	45,5	22,0	37,0	89,6	58,0
oap	-8,1	14,7	3,8	10,2	5,1	11,3
rmk	2,5	3,4	7,7	7,4	10,2	32,8
cmt	-7,6	15,4	15,7	-6,2	-3,0	0,8
omt	-8,1	22,0	10,6	4,6	5,0	-2,8
milk	3,3	11,5	15,4	8,8	35,4	68,8
sugar	-6,7	5,0	-2,2	4,8	14,9	52,2
vol	-11,2	-12,4	20,3	12,8	13,8	57,0
pcr	-10,9	0,0	-8,3	33,0	-49,4	38,7
ofd	6,1	17,1	21,5	6,2	15,1	17,6

[8] If all 'N' markets clear walraslack should be zero.

[9] In the EU regions, MAGNET is linked to CAPRI predictions of output changes in wheat, grains, oilseeds, horticulture, other crops, pigs and poultry, raw milk, red and white meat, dairy, processed sugar, vegetable oils and fats and processed rice.

Thus, Table 3 shows the output results in MAGNET for simulation A and B, where the thirteen sectors marked in bold italics are those which have been linked to available CAPRI predictions in simulation B. The blue (pink) cells indicate those sector/region combinations where the MAGNET model in simulation A has the same (a different) sign as those in simulation B. A cursory examination of the colours shows that for the EU15, sign convergence *in those sectors which are linked* occurs in less than half of cases (six out of thirteen), whilst in the EU10 and BULROM regions, the corresponding figure improves to eight.

It should also be noted that a potentially negative side-effect of this linkage is that whilst there is higher processed sugar and (particularly) processed rice output predicted by the CAPRI linked version of MAGNET, the output of the upstream sectors (sugar cane/beet and paddy rice) falls. In these two specific cases, productivity improves[10] in the downstream sectors to target CAPRI predicted output changes, with the result that less inputs of the corresponding upstream sectors are required. Clearly, when using this type of soft-linkage in a CGE model which relies on a closed system of interlinking equations, if an adjustment is made to a (set of) variable(s) to target 'expected' trends, there will always be (undesired) compensatory effects elsewhere in the system, if not in the upstream markets, then potentially in the factor markets.

Table 4 extends the analysis to include a selection of non EU regions, where once again, those four sectors marked in italics have been linked to CAPRI predictions in simulation B. Of the 32 linked results (i.e., 4 linked aggregates x eight regions), the level of sign convergence between both simulations is relatively good. The standard MAGNET model results show the same sign as the linked MAGNET results in 25 cases, although dairy sector convergence is not very convincing.[11] An even closer inspection shows that in those 25 cases, even the magnitudes in the meat, vegetable oils and sugar sectors are 'broadly' similar. The two regions where the signs are most incongruent are the EU27 and Japan.

A further examination of Table 4 shows that when comparing the meat, dairy, vegetable oil and processed sugar results to 2020 in simulations A and B, the predictions of CAPRI are rather more optimistic for the EU regions and less optimistic for the non-EU regions. As a result, in simulation B, lower (exogenously linked) outputs for non EU regions in these sectors require negative productivity shocks.

[10] As we shall see later, productivity actually falls in most sectors under the conditions of this experiement.
[11] The poorer result in dairy could be due to aggregation bias between the CAPRI dairy sector armington elasticities and the single one used in MAGNET, or differences in the pattern of the CAPRI and MAGNET trade data in the benchmark.

Moreover, the resulting trade opportunities for EU producers in the EU regions would (*ceteris paribus*) generate considerable output rises. Despite better predicted output prospects for EU regions in CAPRI, endogenous negative productivity changes are also required to dampen the endogenous trade reallocation effects owing to the contraction of non-EU region outputs. The result is that in the linked MAGNET model, with lower productivity effects in these sectors, market prices rise (see next section) and welfare falls (see below), when compared with the non-linked MAGNET model results.

Table 4: Regional production changes (%) with and without link to CAPRI

				Simulation A				
NO LINK	**EU27**	**NOAME**	**LATAME**	**SSA**	**CHN**	**JPN**	**AUSNZ**	**ROW**
CEROIL	-1,3	11,9	30,1	52,7	35,2	-9,8	18,0	26,5
INDCROPS	4,4	18,5	33,3	86,3	52,8	-0,5	22,3	27,2
HORT	3,5	8,2	28,8	61,1	48,0	3,2	20,9	33,2
EXTLVSK	-1,1	9,2	36,9	62,1	76,6	-4,2	30,1	28,8
INTLVSK	-4,5	9,0	33,2	62,9	110,0	-14,6	13,5	40,2
MEAT	-2,2	17,3	56,9	72,3	154,7	-6,1	23,7	36,8
DAIRY	5,0	21,4	37,2	43,5	76,0	0,7	35,3	36,5
VEGOIL	-5,9	12,5	49,7	89,8	108,8	-8,4	13,8	73,6
SUGAR	-3,5	12,3	35,4	75,7	71,1	-3,5	11,1	43,7
OFOOD	6,7	18,9	42,4	84,2	88,1	3,7	25,9	47,7
REST	12,6	35,9	62,3	84,2	179,8	19,7	42,0	67,6
				Simulation B				
WITH LINK	**EU27**	**NOAME**	**LATAME**	**SSA**	**CHN**	**JPN**	**AUSNZ**	**ROW**
CEROIL	1,4	29,8	43,5	52,9	33,4	-8,6	21,7	31,1
INDCROPS	-7,8	30,3	44,4	92,7	48,8	6,5	24,6	31,5
HORT	-0,1	12,3	32,4	57,2	44,1	4,0	19,7	32,4
EXTLVSK	21,5	50,2	99,2	141,6	88,0	27,6	65,7	45,9
INTLVSK	9,4	7,7	40,3	68,5	114,9	4,4	23,4	50,4
MEAT	0,4	0,2	25,5	37,0	92,1	-2,4	8,6	23,0
DAIRY	14,0	-12,0	-5,5	21,7	36,8	-47,6	-5,3	52,0
VEGOIL	15,6	14,5	28,8	53,7	66,9	-11,8	57,0	44,2
SUGAR	8,6	11,8	81,5	38,4	25,0	-6,8	35,4	23,1
OFOOD	6,9	19,2	41,8	77,4	82,7	2,8	26,3	46,3
REST	12,4	35,8	60,8	80,8	178,4	19,6	41,4	66,8

3.2 Market prices

As noted in section 2.3, there are no price linkages performed in this study. Notwithstanding, as a gauge of CGE model impacts from linking to CAPRI, Table 5 shows the resulting market price trends in MAGNET under the conditions of simulations A and B. As a general comment, the MAGNET results in both simulations show price falls since projected rises in economy wide productivities (to target real GDP growth) and land productivities generate rightward supply curve shifts, which exceed rightward shifts in the demand curve induced by rises in real income. Comparing simulations A and B, it is clear to see that prices in simulation B are relatively higher. This is due to the additional negative productivity effects described in section 3.1 above which drive up prices, but also, it reflects the fact that overall, world output in 'linked' sectors falls when using CAPRI model predictions. those sectors is lower when linking the MAGNET results across regions to the CAPRI predictions (compared with the standard MAGNET results). For example, this clear trend is observed when comparing the world output of the standard MAGNET results and MAGNET-CAPRI linked results (not shown) for meat (29.3% and 15.8%, respectively), dairy (19.8% and 13.3%, respectively), vegetable oils and fats (54.0% and 38.2%, respectively) and processed sugar (30.6% and 28.6%).

Table 5: Regional market price changes (%) with and without link to CAPRI

	Simulation A							
NO LINK	**EU27**	**NOAME**	**LATAME**	**SSA**	**CHN**	**JPN**	**AUSNZ**	**ROW**
CEROIL	-27,8	-29,2	-32,5	-36,4	-19,4	-32,3	-27,6	-23,7
INDCROPS	-27,1	-22,8	-30,6	-30,9	-4,8	-30,1	-22,7	1,4
HORT	-27,3	-26,8	-33,1	-35,2	-18,2	-29,4	-26,7	-16,5
EXTLVSK	-26,2	-30,0	-38,2	-38,8	-22,0	-30,5	-29,0	-16,8
INTLVSK	-25,9	-30,4	-36,7	-35,5	-49,7	-28,8	-30,0	-36,2
MEAT	-22,4	-29,4	-37,8	-33,9	-57,9	-26,4	-29,6	-33,5
DAIRY	-21,3	-28,1	-35,8	-21,4	-52,9	-22,7	-31,3	-28,3
VEGOIL	-24,1	-31,3	-35,7	-34,4	-46,7	-28,1	-30,4	-33,5
SUGAR	-20,5	-26,9	-34,0	-34,0	-46,1	-20,5	-24,8	-27,6
OFOOD	-18,9	-23,6	-30,8	-25,3	-42,9	-21,1	-24,1	-29,7
REST	-16,5	-15,4	-18,3	-21,5	-24,3	-11,8	-16,3	-20,1
	Simulation B							
WITH LINK	**EU27**	**NOAME**	**LATAME**	**SSA**	**CHN**	**JPN**	**AUSNZ**	**ROW**
CEROIL	-13,4	-21,4	-22,3	-30,0	0,9	-27,9	-16,0	-11,5
INDCROPS	-5,7	-15,5	-21,8	-22,3	10,5	-25,6	-11,5	17,8
HORT	-14,9	-24,0	-28,3	-30,3	-2,3	-25,7	-18,8	-8,5
EXTLVSK	-10,9	-19,2	-21,1	-30,4	7,8	-22,4	-15,0	-4,7
INTLVSK	-21,4	-24,3	-28,5	-31,6	-46,6	-23,3	-22,4	-31,2
MEAT	8,4	41,7	48,4	83,7	-13,9	21,7	62,2	57,4
DAIRY	-20,3	26,5	22,0	2,8	-26,1	73,8	-0,1	-33,7
VEGOIL	-9,7	-4,9	17,8	51,0	4,5	3,4	20,4	29,3
SUGAR	-33,4	-17,9	-46,5	-36,5	20,3	-3,0	-36,9	6,3
OFOOD	-16,6	-21,9	-28,7	-25,0	-38,0	-18,7	-22,0	-26,8
REST	-16,5	-15,4	-17,8	-21,7	-24,9	-12,3	-15,9	-20,2

3.3 Trade

Trade quantities in MAGNET are not linked to CAPRI in our experiments, since this would require even more closure swaps (greater disruption to the model). Furthermore, the robustness of the MAGNET model could potentially be compromised when making a significant number of quantity shocks, thereby generating greater disruption to other parts of the model which must adjust to accommodate the (potentially drastic) change in trade patterns resulting from the PE model. Instead, examining the sign of each CAPRI prediction, this section assesses the extent to which MAGNET results linked to CAPRI output predictions, generate greater convergence to the CAPRI trade predictions when compared with the standard MAGNET model solution.[12]

Table 6 presents the changes in import quantities predicted by the MAGNET model in simulation B (i.e., when linked to CAPRI output) for those (twelve) sectors where CAPRI predictions were available to GTAP concordance. The colours are fourfold and explicitly represent a comparison between three sets of results:

(i) standard MAGNET model export results

(ii) linked MAGNET model export results

(iii) CAPRI generated export results.

Thus, the **blue** cells are those cases where both sets of MAGNET results are consistent with the signs predicted in CAPRI. The **orange** cells are when neither set of MAGNET results are consistent with CAPRI predicted signs. The **green** cells are the cases where MAGNET results linked with CAPRI output predict the same sign as CAPRI, whilst standard MAGNET results predict a different sign to CAPRI. Finally, the **pink** cells are those cases where MAGNET results linked with CAPRI output predict a different sign to CAPRI, whilst standard MAGNET predict the same sign as CAPRI.

Table 6: Reported import changes (%) in MAGNET (linked to CAPRI output)

	wht	gro	oils	hort	ocr	oap	cmt	omt	mil	sgr	vol	pcr
EU15	20,6	13,7	8,8	10,4	25,3	14,3	-15,1	7,5	21,6	15,1	-14,2	-4,2
EU10	3,3	10,0	13,1	8,5	125,9	22,9	32,3	5,3	-16,6	-4,6	14,0	78,2
BULROM	-20,0	-11,1	6,6	37,0	59,2	14,0	-12,1	97,9	-70,4	-35,4	-75,0	-60,5
REU	-3,7	0,5	29,1	6,4	8,2	15,7	-30,6	14,1	55,3	36,2	-29,7	55,2
TUR	26,4	36,0	60,9	41,1	17,5	48,4	39,2	109,4	-77,4	99,5	107,9	45,2
RUSPlus	15,8	3,9	28,2	9,9	6,4	23,7	289,9	5,6	35,8	180,3	24,7	29,5
MIDEAST	29,1	26,9	36,7	25,1	27,2	39,3	23,5	39,5	33,7	57,9	21,5	26,1
CHN	71,6	80,6	98,4	147,2	210,4	43,8	93,7	10,7	23,7	467,0	56,2	72,7
JPN	-7,2	-5,4	-6,0	-9,7	-19,6	13,0	-23,4	14,2	420,8	39,5	-11,5	1,3
INDO	32,5	0,9	86,6	28,6	22,2	35,8	35,4	26,2	159,8	55,8	199,9	-17,2
KOR	10,9	9,6	16,6	2,0	22,6	21,9	-36,9	35,6	156,9	37,6	-50,2	-15,5
INDPAK	384,3	95,8	491,5	187,4	460,4	67,2	441,5	1071,2	-82,1	597,4	113,5	59,7
RoASIA	24,0	32,4	102,1	18,4	22,8	45,0	117,5	105,4	82,7	51,3	44,8	5,3
USA	10,2	20,5	8,5	10,7	25,6	21,1	5,7	2,7	670,2	94,5	25,5	41,7
CAN	8,0	12,8	17,1	14,5	5,2	22,1	250,5	33,3	138,5	71,9	-35,0	13,6
MEX	7,7	11,4	42,8	21,7	9,6	38,9	80,0	54,0	-65,3	530,7	-77,3	23,3
ARG	15,4	40,6	108,6	13,8	24,7	64,7	1274,1	-4,2	176,9	2794,8	55,8	24,0
BRA	16,9	26,7	19,6	28,8	15,1	38,6	93,5	36,7	64,1	-60,3	360,6	21,1
RoSA	14,5	16,2	40,9	16,0	11,2	40,8	48,6	-3,0	352,5	86,4	54,4	22,5
NAFR	40,7	38,8	49,8	76,8	72,6	44,2	43,5	86,8	36,0	130,6	33,5	66,5
SSA	28,5	35,9	64,2	41,4	39,5	74,9	232,8	133,4	160,5	121,8	87,5	47,0
ANZ	43,4	30,6	29,5	23,6	20,1	38,5	34,4	16,0	88,2	18,3	-12,1	48,2

[12] The observations which follow in this section apply to a representative baseline scenario consisting of CAP shocks in both models. On the basis of this study, it is not possible to generalise the findings to other baselines including additional policy shocks (i.e., trade, greenhouse gases, biofuels etc.).

Looking at Table 6, the blue cells dominate the orange ones by approximately a 2:1 ratio, implying that by a clear margin, both sets of MAGNET results are reasonably consistent with the CAPRI import trade predictions. In some regions, the level of congruence (blue cells) across the three sets of results is quite high (e.g., RUSPlus, MIDEAST, INDPAK, INDO, RoASIA, SSA, ANZ); whilst in other regions (e.g., EU15, BULROM, KOR, USA, CAN, ARG, BRA) the larger number of orange squares shows that the convergence of both sets of MAGNET results with the CAPRI predictions is relatively poor. This latter situation typically occurs when CAPRI predicts a fall in imports to a particular region.[13]

Examining the frequency of the green and pink cells in Table 6 allow us to compare between the two sets of MAGNET results. For example, there are 21 sector/region cases (green cells) of a better sign convergence with CAPRI import results when using the CAPRI linked MAGNET model, compared with 23 sector/region cases (pink cells) of a worse sign convergence with CAPRI results when using the CAPRI linked MAGNET model. Thus, neither set of MAGNET import results shows a greater degree of sign convergence to the CAPRI import predictions.

[13] 'Typically', imports in the CGE model rise as regional real incomes increase (rising marginal propensity to import) due to projected increases in factor endowments. This effect is absent in the CAPRI model.

Table 7: Reported export changes (%) in MAGNET (linked to CAPRI output)

	wht	gro	osd	v_f	ocr	oap	cmt	omt	mil	sgr	vol	pcr
EU15	-17,3	-15,7	4,9	-2,3	-18,5	9,6	47,9	2,8	19,2	-12,7	104,4	89,9
EU10	20,0	4,7	6,5	-16,5	-91,0	-10,9	40,4	7,7	268,1	17,6	39,4	-83,9
BULROM	135,7	137,6	91,7	-44,2	-59,9	11,3	116,8	-72,6	2523,2	367,6	3355,4	373,3
REU	32,6	22,0	28,8	31,0	59,8	10,1	545,5	8,9	-33,0	-24,7	120,5	-32,0
TUR	125,1	40,2	106,3	27,4	117,9	13,3	97,8	-93,0	7464,4	-49,3	17,8	-39,7
RUSPlus	95,5	54,5	170,8	79,2	93,4	55,5	-60,8	63,8	26,9	-90,9	5,8	-3,3
MIDEAST	63,2	51,5	105,8	48,2	82,8	53,9	147,2	40,6	229,7	44,5	105,1	6,7
CHN	4,2	-37,4	-59,4	-35,2	-74,6	146,6	502,7	255,0	274,4	-96,4	74,9	-9,6
JPN	89,6	39,4	120,7	58,9	260,2	15,5	184,8	19,1	-99,5	-81,2	36,7	-22,5
INDO	65,2	79,4	44,5	69,1	122,6	88,8	125,3	126,3	-92,2	-30,1	-56,9	167,3
KOR	61,6	61,4	62,9	45,7	61,7	78,5	1221,6	-10,1	-21,6	116,3	318,7	100,5
INDPAK	-86,4	-44,9	-89,6	-66,8	-89,1	43,8	-68,6	-99,3	9896,6	-95,9	0,8	4,9
RoASIA	149,0	70,8	23,8	86,0	96,3	41,2	-62,0	-35,7	-15,4	68,1	16,0	46,0
USA	26,9	19,1	75,5	34,5	81,8	27,4	92,4	31,3	-86,4	214,5	-19,9	-24,6
CAN	38,0	28,0	54,1	32,3	56,1	-2,1	-85,7	-12,1	-68,2	-36,9	647,1	-29,9
MEX	114,7	40,8	38,6	29,2	99,1	16,1	-49,0	-37,7	834,2	-98,9	6560,9	-34,7
ARG	36,6	26,3	35,4	40,2	79,0	14,1	162,0	105,1	-10,1	-100,0	118,7	47,1
BRA	250,3	55,9	80,4	32,9	90,7	18,1	8,8	23,0	62,0	328,6	-78,7	4,7
RoSA	68,0	46,1	56,5	42,3	74,7	46,8	116,1	193,1	-92,8	28,9	2,4	-0,7
NAFR	-3,8	-5,6	-30,9	-24,6	17,9	55,3	-50,4	-19,6	51,1	-4,6	-4,5	-39,4
SSA	161,7	65,1	157,4	87,6	162,2	56,4	-61,9	-34,0	-43,0	31,2	24,9	31,9
ANZ	-16,0	35,5	23,9	18,6	24,8	17,9	11,6	32,4	-19,5	42,4	116,3	-36,9

In Table 7, an equivalent table of export results is presented. Although the blue cells remain more dominant compared with the orange cells (109 and 82 cells, respectively), in relative terms the degree of congruence of the two sets of MAGNET export results with the CAPRI sign predictions, is not as strong in the case of the imports. Looking at the relative frequency of green and pink squares by region, we see that the MAGNET results linked to CAPRI output more often show improved congruence with CAPRI export predictions in the EU15, EU10, REU, RUSPLus, JAP, CAN, MEX, BRA, RoSA. On the other hand, the MAGNET results linked to CAPRI output produce less congruence in the regions INDO, NAFR, SSA, and ANZ. On balance, there are 48 cases of improved congruence (green cells) vis-a-vis 25 cases of worse congruence (pink cells). Thus, the MAGNET results linked to CAPRI output produce, by a margin of 2:1, a more consistent story line with the CAPRI model.

3.4 Welfare

Examining the welfare results in Table 8, a comparison between the standard MAGNET results and the CAPRI-linked MAGNET results shows a clear pattern. Real incomes in all regions are scaled downwards when linked to the CAPRI results, since negative productivity effects are required to meet CAPRI output predictions (see section 3.1). In general, the relative order of the welfare gains across the regions remains unchanged when comparing the two sets of MAGNET model results.[14]

Table 8: Reported change in per capita utility (%) with and without CAPRI output linkage

	no link	link		no link	link
EU15	4,2	3,6	**INDPAK**	90,1	88,4
EU10	32,1	30,8	**RoASIA**	52,4	50,3
BULROM	42,9	40,5	**USA**	29,9	28,7
REU	18,5	17,3	**CAN**	15,8	13,9
TUR	26,7	24,1	**MEX**	34,8	33,0
RUSPlus	60,2	53,9	**ARG**	0,8	0,7
MIDEAST	29,1	27,6	**BRA**	48,2	45,3
CHN	164,4	161,2	**RoSA**	43,2	39,0
JPN	27,0	26,0	**NAFR**	35,6	31,3
INDO	67,0	62,7	**SSA**	39,0	32,2
KOR	50,2	49,0	**ANZ**	2,7	2,6

3.5 Overview and Conclusions of the 'test bed' study

A fundamental point to understand is that any type of model linkage is fraught with difficulty since major model differences exist, in terms of the data, the assumed behavioural parameters and the underlying structural mechanisms of the two models. This, however, does not mean that such a linkage should not be attempted, but rather one should have realistic expectations on what can be achieved when trying to harmonise different modelling approaches. As a starting point, this test bed study attempts to introduce a systematic 'soft linkage' by targeting real output changes in the CGE model, based on predictions within the CAPRI model. The advantage is that such an approach is relatively straightforward to implement, although some degree of experimentation with different shocks combinations may be necessary to generate robust CGE results. On the other hand, the issue is whether such a linkage significantly improves the degree of convergence between the models under consideration and indeed, whether the side effects to other aspects of the CGE model warrant such an approach.

As a basis for this experiment, two simulations reflecting a CAP baseline of the MAGNET model are run. In simulation A, the results of a standard MAGNET CAP baseline are presented, whilst in simulation B, the same shocks are run with the addition of predicted agri-food sector output shocks taken from a CAPRI CAP baseline. The latter is an attempt to implement a systematic form of soft model linkage, based

[14] Once again, it is not possible to say whether this is a robust finding across many different baselines.

on the targeting of sectoral outputs. To improve the consistency of the experiments, efforts are made to harmonise the time period, the structure of the experiment (i.e., comparative static) and the sectoral and regional aggregation and the macro baseline shocks. For the reasons highlighted above, no attempt was made to conduct a detailed comparison of model results, but rather focus on the more subjective criteria of the signs of the results.

It is found that the standard MAGNET model and the CAPRI model predictions implemented in MAGNET, 'more often than not', predict the same signs for output. In the EU15, where a more significant number of agri-food sectors are linked, there are quite a few sign differences between CAPRI predictions and those of standard MAGNET, whilst in the non-EU regions, the level of convergence is generally good (although CAPRI output shocks are only imposed on five food sectors). If the calibrated CAPRI output predictions (or indeed, those from any non-MAGNET model) are really considered as more plausible, then on the basis of this evidence, it suggests that there is a clear need to have some form of linkage between the models, especially if the focus is on the EU.

Examining the import and export predictions, a subsequent analysis examines the degree of convergence between the CAPRI results and those of the two sets of MAGNET results (i.e., with CAPRI output linkage and without CAPRI output linkage). In the case of the import trends, there is no evidence to suggest that when linked to CAPRI output predictions, the MAGNET and CAPRI results become more congruent. On the other hand, there is (limited) evidence on the export side, that linked MAGNET results do provide better congruence to CAPRI. Despite the fact that trade within a CGE model is also affected by capital account movements and changes in real income from (*inter alia*) factor accumulation (neither effect is present in the CAPRI model), this finding is perhaps not too surprising, given that manipulating output in a CGE model has a more direct impact on exports than on imports.

A further aim of the study is to briefly assess how this method of systematic soft linkage affects MAGNET results elsewhere, when compared to a standard set of MAGNET results. Examining the market prices trends in those food sectors where outputs are linked globally to CAPRI, it is found that there are very significant relative price rises to the point where market prices actually rise in absolute terms over the time frame of the experiment. This result occurs because of the considerably lower global supply response predicted by CAPRI (vis-à-vis standard MAGNET).

It is also noted that using productivity to target output, can generate unwanted side-effects elsewhere, as evidenced in the case of the results for EU upstream sectors paddy rice and sugar beet/cane. Indeed, this effect is symptomatic of a general problem in that targeting one part of the system, inevitably affects other variables, which then opens the debate on whether the results are affected to such a degree, that they become implausible when judged against *a priori* expectations. Indeed, even if we had used a different soft-linking approach to target output (e.g., output taxes), instead of facing distortions on input/factor markets, one would now be potentially generating unwanted fiscal and allocative efficiency effects within the model.

It is also observed that the resulting reductions in productivity required in many sectors to target CAPRI output changes also reduce welfare outcomes in MAGNET. In the context of the current experiment, the message of the MAGNET model is unchanged (i.e., the relative welfare impacts across the regions remains the same). It is plausible that for developed countries, endogenous productivity adjustments in agri-food sectors will have a small impact on welfare, given the relative size of these activities in the broader economy. On the other hand, in less developed countries, such a restriction may have a deeper impact on welfare (and therefore the rest of the economy), owing to the stronger role of the agriculture and food sector. In the context of the current experiment, this finding is certainly confirmed, and thus, this 'cost' should be considered if attempting a soft model linkage of this type.

Taking these pragmatic modelling issues into consideration, one may be led to question whether such a direct soft approach to model linkage should be used at all. Indeed, it may be better to focus more or aligning the responsiveness (i.e., the elasticities), such that a consistent 'behavioural pattern' is established in both models without the need to impose conditional (exogenous) restrictions, which may owe more simply to structural differences in modelling approaches rather than any superior treatment of the functioning of real domestic and world agricultural markets. On this note, in the next section, an assessment of a 'hard' linkage approach is discussed.

4. Exploring structural (hard) model linkages: A review

4.1 Background

In the context of the current overview, two scientific papers are identified (Britz and Hertel, 2011; Pelikan *et al.*, 2015) to be of particular relevance as a basis for conducting further policy orientated work involving a more 'structural' approach to model linkages. Interestingly, in the abstract of Britz and Hertel (2011, pp.102), it is argued that, *"The applicability of this combined modelling approach...holds great* *promise for future, cross scale analysis of global issues bearing on agriculture, land use and the environment"*.

In section 4.2, the general aim of both papers is discussed. Section 4.3 takes a closer look at the technical aspects of the approach, whilst section 4.4 considers some of the potential modelling challenges if one were wishing to replicate such an approach for a more complex model such as MAGNET. Section 4.5 concludes with some recommendations for further work.

4.2 Paper description

Britz and Hertel (2011) examine the impacts of EU biofuels mandates on global land usage and EU environmental indicators. In a similar vein, Pelikan *et al.*, (2015) which, from a methodological standpoint, follows on directly from Britz and Hertel (2011), focuses on a broader common agricultural policy (CAP) reform scenario involving the implementation of the proposed Ecological Focus Area (EFA) restrictions on agricultural supply response in the European Union. Pelikan *et al.* (2015) consider the European Commission proposal of 2011[15] which required that farmers assign seven percent of their non-pasture farmland to the EFA requirement in order to qualify for first pillar decoupled farm payments under the single farm payment (SFP) scheme. In practice, this compulsory regulation obliges farmers to engage in a number of non-commercial or non-intensive farming practices including buffer strips, catch crops, cover crops, nitrogen-fixing crops, fallow land, and hedges.

A major scientific contribution of both papers is that the economic and environmental impacts of the policy under consideration are measured at a global and local regional level by combining two well-known market model approaches (one partial equilibrium (PE) and one computable general equilibrium (CGE)) in a mutually consistent way. More specifically, both applications employ the 'response surface approach' pioneered by Britz and Hertel (2011), which forges a structural link between the supply response elasticities of both model frameworks. The underlying idea is that predicted outcomes at both spatial levels can only be considered consistent if the PE-CGE analysis is coherent.

Thus, to examine the impacts of policy reform at a high degree of spatial disaggregation and farm type detail, the CAPRI PE market model (Britz and Witzke, 2014) employs a farm module (Gocht and Britz, 2011) which includes a spatially

[15] A modification of this proposal was already on the table at the time of this paper, but no concrete details were available.

detailed account of agricultural supply and CAP measures. Given its econometric foundation based on the supply response work of Jansson and Heckelei, (2011), the CAPRI model serves as an ideal starting point for the generation of supply elasticities. More specifically, supply response in the crops sectors involves the maximisation of revenues subject to a (fixed) production possibilities frontier. The resulting first order conditions can be solved to generate compensated supply functions, whilst the second-order derivatives yield own- and cross-price compensated supply elasticities (see later). [16]

The global land use and emissions impacts are explored employing a land use variant of the well-known Global Trade Analysis Project (GTAP) model (Hertel, 1997) and accompanying data set, called GTAP-AEZ (Agro-Ecological Zones) (Lee *et al.*, 2009). In addition to the standard features inherent within GTAP, GTAP-AEZ also includes additional land use data covering 18 AEZs with six growing periods and three climatic zones, as well as comprehensive set of greenhouse gas data linked to land usage based on a carbon accounting model. In the Britz and Hertel (2011) application, the GTAP model is also extended to include a specific biofuels module (it is not clear if this module is maintained in Pelikans et al., 2015).

4.3 Model linkage steps

To facilitate compatibility between the PE and CGE models, crop outputs in CAPRI are aggregated to meet the sectoral mapping of the six GTAP crop sectors.[17] Modifications to the CAPRI model code are implemented to fix intermediate inputs and factors, first pillar subsidies and livestock activities. It is supposed that this provides the basis upon which a correct calculation of compensated supply elasticities within the CAPRI model framework can be conducted. Subsequently, sensitivity analysis was implemented by increasing the price of each of the six crop activities by 5 per cent against the base year in CAPRI, and then aggregating the resulting compensated supply elasticities up to the EU27 level employing a Laspeyre's index. In short, this enables the authors to generate a Hessian matrix of (second-order) own- (i=j) and cross-price (i≠j) compensated supply elasticities.

[16] Revenue is maximised subject to a (fixed) production possibilities frontier characterised by fixed inputs. Thus, there is a substitution effect between different crop outputs given fixed inputs. The (Hicksian) output supplies are 'compensated' because before and after any output price changes, total revenues must adjust given that total crop production remains unchanged.

[17] Wheat, rice, other grains, oilseeds, sugar crops, other crops.

To integrate the compensated supply elasticities generated by CAPRI into GTAP, in the GTAP model equations, a single multi-product revenue maximisation problem is added to the GTAP-AEZ model. More specifically, a normalised quadratic revenue function (Diewert and Wales, 1988) is used, where revenue is maximised for a given vector of normalised output prices[18] and composite intermediate inputs and primary factors.[19] Due to the functional flexibility of the underlying revenue function, the compensated supply elasticities generated from the CAPRI experiments (i.e., in the Hessian matrix), can be calibrated directly into the resulting linearised crop output supply functions in GTAP as behavioural parameters.

As a departure from the approach in Britz and Hertel (2011), Pelikans et al. (2015) add an additional layer of structural model linkage in that they also seek to reconcile the *uncompensated* supply elasticities (ε^{u}_{ij}) generated in both model approaches. Examining the technical appendix to Pelikans et al. (2015), the authors derive a formula which details the relationship between the uncompensated supply elasticity and the compensated supply elasticity (ε^{c}_{ij}) as follows:

$$\mathcal{E}^{u}_{ij} = \mathcal{E}^{c}_{ij} + \frac{\partial Q_i}{\partial X}\frac{\partial X}{\partial R}\frac{\partial R}{\partial p_j}\frac{p_j}{Q_i} = \mathcal{E}^{c}_{ij} + \left(\frac{\partial Q_i}{\partial X}\frac{X}{Q_i}\right)\left(\frac{\partial X}{\partial R}\frac{R}{X}\right)\left(\frac{\partial R}{\partial p}\frac{p_j}{R}\right) = \mathcal{E}^{c}_{ij} + \Omega\theta_j \qquad (1)$$

where X are aggregate inputs, Q_i is output of crop 'i', R is aggregate revenue in crops sectors, and p_j are crop prices in sector 'j' (for i=j and i≠j). Assuming linear homogeneity in inputs and outputs in the underlying revenue function,[20] then in simplified form ε^{u}_{ij} is equal to ε^{c}_{ij} plus the elasticity of aggregate input supply to changes in aggregate crop sector revenue (Ω) multiplied by the change in the share of crop j in total crop revenues (ϑj).

The idea of the latter two concepts (Ω and ϑj), known collectively as the 'expansion effect', in that if there are higher returns for crop 'j', then the rise in total revenues in the crop sector is a function of the share of crop 'j' in total revenues (the bigger the revenue share, the greater the rise in aggregate crop revenues). With

[18] Output prices are normalised by the N'th crop commodity price. Reading both papers, it is understood that the EU27 crop with the largest revenue share is employed as the numeraire in the GTAP model.
[19] In Pelikans et al. (2015), the functional form is modified to account for the EFA constraint (i.e., land not usable in commercial production).
[20] i.e., $\left(\frac{\partial Q_i}{\partial X}\frac{X}{Q_i}\right) = 1$

increased revenues or resources in crop production, more factors move into these sectors generating an aggregate increase in *all* crop outputs.[21]

To provide values of uncompensated supply elasticities, once again the CAPRI model is taken as a starting point. It is understood that an 'unrestricted' version of the CAPRI model is run (i.e., intermediate inputs and factors, first pillar subsidies and livestock activities are no longer held fixed) where the price of each of all six crop activities is uniformly increased by a certain percentage, thereby deriving an aggregate 'crop' sector expansion effect.

Taking this expansion effect and adding to the compensated elasticities from CAPRI (see equation 1), gives the 'targeted' partial equilibrium uncompensated elasticities for the GTAP-AEZ model. To capture the magnitude of this additional expansion effect within the GTAP model, adjustments are made to the land mobility parameter. In GTAP-AEZ, the transformation of land across using sectors follows a layered nesting structure where in the top nest aggregate land transformation is modelled between alternative uses of composite crops, pasture and forestry activities, whilst a lower 'crops' nest explicitly treats land transformation possibilities between arable activities. It is by adjustments to the lower CET crop transformation elasticity that the expansion effect is targeted. The results on Table 1 (Pelikans et al., 2015, pp.8) show a close approximation, although exact matching is said to be difficult because there are 'general equilibrium' expansion effects in GTAP(-AEZ) which are not crop (or agricultural) specific (Pelikans et al., 2015, pp. 7) resulting, one assumes, from changes in labour and capital allocation across all sectors.[22]

Once these structural linkages are achieved, the GTAP model is run (with calibrated compensated supply elasticities in the crop output supply functions and a modified CET parameter on arable land uses) with the addition of relevant policy shocks (i.e., biofuels mandates, CAP policy reform). The resulting crop output prices are fed back exogenously into the CAPRI model in order to examine the impacts at a detailed spatial degree of disaggregation on land usage and the environment.

4.4 Practical modelling considerations and challenges

[21] In microeconomic terms, it is the same as saying that the iso-revenue function shifts to the right, allowing an optimal revenue maximising equilibrium on a higher production possibilities frontier (PPF).

[22] Discussing with Janine Pelikan, it was discovered that approximately 30 runs were required to match the uncompensated elasticities in GTAP-AEZ with the CAPRI model.

- The crop supply equations derived from the revenue maximisation problem are coded into the GEMPACK file, thereby allowing direct calibration of compensated supply elasticities (from CAPRI). The crop markets are now supply driven. From a closure perspective, this suggests that the cost minimising demand structure may now be removed from the code (in favour of revenue maximising supply functions), where demand is now determined by the market clearing equations. This would need to be examined more closely.
- The applications discussed above use a comparative static version of GTAP-AEZ which is much simpler than the MAGNET model. There was no attempt made to test this linkage mechanism with a more aggressive set of shocks (i.e., projections, multiple policy shocks). As a result, it remains unclear as to whether the model would be robust under these circumstances. However, informal feedback from Janine Pelikan suggested that even with a small shock (i.e., set aside), the walraslack was -0.05, although the results appeared robust for a series of different set aside rates. No serious sensitivity analysis using other types of shocks was undertaken.
- A perceived advantage of this approach appears to be that there is no need to implement any type of partial equilibrium closure or any restrictions on any variables in the CGE model to implement the compensated and uncompensated PE supply elasticities. Indeed, the linkage is entirely parametric (i.e., via behavioural parameters), whilst the CAPRI model does not necessarily need to be compromised at all (i.e., the loss of the CAPRI market module) if one chooses NOT to feed back crop price results from the GTAP-AEZ model. Indeed, if one feeds back 'aggregate' crop prices from GTAP to CAPRI, one is also making the (strong) assumption that all CAPRI crops within corresponding aggregate sectors face the same price change. Moreover, the CAPRI global market module includes more agricultural markets detail as compared to GTAP. Not using this module might result in biased results especially when agricultural trade flows are affected.
- When targeting GTAP to the uncompensated elasticities of supply, the fine tuning of GTAP's CET land transformation elasticity between crops requires a large number of simulation runs to find an optimal value. It was suggested by Janine Pelikan that it took up to thirty simulation runs (by trial and error) to mimic the CAPRI target values in their paper (Pelikan *et al.*, 2015). Some optimisation method might be required to improve this.
- On a related note, the MAGNET model employs a much more complex land transformation nest. In light of the above discussion, it becomes quickly

apparent that targeting uncompensated elasticities in MAGNET would be more complicated than relatively 'simple' model such as GTAP-AEZ. The alternatives are to (i) assume a similar CET structure to GTAP-AEZ (thereby losing the land transformation detail in MAGNET); (ii) ensure that crops CET nests are all separated from other land uses and apply the same CET elasticity in all or (iii) employ a more complex CET structure typical of MAGNET, but face the prospect of a greatly increased computational cost in finding optimum target values. An optimisation program would ease the computational burden considerably, although how this could be implemented both conceptually and practically, would have to be carefully thought out.

- If such an analysis were to be replicated for a recursive dynamic model (such as MAGNET) one would have to update both the PE (CAPRI) and CGE (MAGNET) representations to each period and redo the procedure for each time interval. In light of the above issues, this would require considerably more time to implement, although once again, this could be reduced if a useful optimisation program could be developed to reduce the number of simulations required to target CAPRI uncompensated elasticities.
- In a similar manner, the two studies reviewed above only contemplate a single EU27 region in GTAP. If one is to make the most of the MAGNET CAP budget own-resources module (which requires disaggregated member states), then once again, the computational cost of targeting uncompensated supply elasticities for multiple EU regions (and even potentially non EU regions) rises considerably. Once again, this points to the need for an optimisation program of sorts to mitigate this modelling problem.

4.5 Conclusions

The authors of these papers offer an elegant method for structurally linking two model approaches. Intuitively, the approach has considerable appeal since one does not have to impose heavy restrictions in either of the two models (especially if, in CAPRI, one does not pass back crop supply prices from the GTAP model). A discussion at the Institute for Prospective Technological Studies (IPTS) in Seville on the 21st January with both PE and CGE modelling experts lead to the conclusion that such an approach would be worth pursuing for potential policy orientated work for the European Commission (DG AGRI). A further discussion between model experts at IPTS and LEI came to a consensus that a 'pilot' type study could be a useful first step. This could involve a stylised policy scenario linking the MAGNET model and the CAPRI model. This would be compared with the 'standard' approach of running the same policy run for both models in isolation and then compare the degree of congruence of the results in both models with the linkage method. On this basis, the practical implications of the modelling issues highlighted in section 4 above could be genuinely assessed, as well as the quality of the model results under both approaches.

5. References

Anderson, K. & Tyers, R. (1988) Liberalising OECD Agricultural Policies in the Uruguay Round: Effects on Trade and Welfare, *Journal of Agricultural Economics*, 39, pp197-216.

Anderson, K. & Tyers, R. (1993) More on Welfare Gains to Developing Countries from Liberalising World Food Trade, *Journal of Agricultural Economics*, 44, pp189-204.

Boulanger, P. and Philippidis, G. (2015) The EU Budget Battle: Assessing the Trade and Welfare Impacts of CAP Budgetary Reform, *Food Policy*, Vol. 51, (2015) pp. 119-130. Available at http://dx.doi.org/10.1016/j.foodpol.2015.01.004

Britz, W. and Hertel, T. (2011) Impacts of EU biofuels directives on global markets and EU environmental quality: An integrated PE, global CGE analysis, *Agriculture, Ecosystems and Environment*, v142, pp102-109.

Britz W, Witzke P (eds) (2014) CAPRI model documentation 2014. http://www.capri-model.org/docs/capri_documentation.pdf.

Burniaux, J.M. & Waelbroeck, J. (1985) The Impact of the CAP on Developing Countries: A General Equilibrium Analysis, in, *Pressure Groups, Policies and Development*, Stevens, C. and Verloren van Themat, J. (eds), Hodder and Stoughton, London.

Diewert, W.E . and Wales, T.J. (1988) A normalised quadratic semiflexible functional form, Journal of Econometrics, v37, pp327-342.

Gocht, A. and Britz, W. (2011) EU-wide farm type supply models in CAPRI – How to consistently disaggregate sector models into farm type models, Journal of Policy Modelling, v33, pp146-167.

Helming, J.F.M., S. Jansen, H. van Meijl and A. Tabeau (2010). European farming and post-2013 CAP measures; A quantitative impact assessment study. LEI Report 2010-085. LEI, part of Wageningen UR, The Hague.

Heckelei T (2002) Calibration and Estimation of Programming Models for Agricultural Supply Analysis. Habilitation Thesis, University of Bonn

Hertel, T. W. (Ed) 'Global Trade Analysis: Modeling and Applications' (Cambridge University Press, 1997)

Himics, M., Artavia, M., Hélaine, S., & Boysen, O. (2014). Calibrating the CAPRI and ESIM models to the mid-term commodity market outlook of the European Commission: Institute for Prospective and Technological Studies, Joint Research Centre.

Jansson T. and Heckelei, T. (2011) Estimating a primal model of regional crop supply in the European Union, *Journal of Agricultural Economics*, v62, pp137-152.

Loo, T. & Tower, E. (1989) Agricultural Protectionism and the Less Developed Countries: The Relationship between Agricultural Prices, Debt Servicing Capacities, and the need for Development Aid, in, *Macroeconomic Consequences of Farm Support Policies*, Stoeckel, A.B., Vincent, D. & Cuthbertson, S., Duke University Press, Durham.

Lee, H.L., Hertel, T.W., Rose, S. and Avetsiyan, M. (2009) 'Economic analysis of land use in global climate change policy', in Hertel, T.W., Rose, S. and Tol, R. (eds), *An integrated land use database for CGE analysis of climate policy options* (Abingdon: Routledge Press, 2009, pp72-88).

Narayanan, G., Badri, Angel Aguiar and Robert McDougall, Eds. 2015. *Global Trade, Assistance, and Production: The GTAP 9 Data Base*, Center for Global Trade Analysis, Purdue University

Nowicki, P., C. Weeger, H. van Meijl, M. Banse, J. Helming, I. Terluin, D. Verhoog, K. Overmars, H. Westhoek, A. Knierim, M. Reutter, B. Matzdorf, O. Magraff and R. Mnatsakanian (2006) Scenar2020 – Scenario study on agriculture and rural development, Contract No 30-CE-0040087/00-08. European Commission, Directorate-General Agriculture and Rural Development, Brussels.
http://ec.europa.eu/agriculture/agrista/2006/
scenar2020/final_report/scenar2020final.pdf

Nowicki, P., V. Goba, A. Knierim, H. van Meijl, M. Banse, B. Delbaere, J. Helming, P. Hunke, K., Jansson, T. Jansson, L. Jones-Walters, V. Mikos, C. Sattler, N. Schlaefke, I. Terluin and D. Verhoog (2009) Scenar 2020-II – Update of Analysis of Prospects in the Scenar 2020 Study,
Contract No. 30–CE-0200286/00-21. European Commission, Directorate-General Agriculture and Rural Development, Brussels.
http://ec.europa.eu/agriculture/analysis/external/scenar2020ii/report_en.pdf

Pelikan, J., Britz, W. and Hertel, T. (2015) Green light for Green Agricultural Policies? An Analysis at Regional and Global Scales, *Journal of Agricultural Economics*, v66(1), pp1-9.

Woltjer, G., and Kuiper M. (eds) (2014). The MAGNET model - Module description. LEI Wageningen UR Report 14-057. The Hague.

Operating instructions in DSS

The experiments are based on the AgriFood2030 model and use the macro projections provided by CAPRI, land productivities of the MAGNET model, and the CAP baseline shocks in CAPRI.

In the database tab in DSS, use NagnetBio_CAP_GHG_Nutrition

Ensure that SHR in the 14_CAPdata.har is configured such that all SFP will all be allocated to land (**mark the row 'land' with 1's and leave the other rows as zeroes**). In this way, we follow the standard assumption of the EC that the SFP is perfectly decoupled from production.

In DSS, **ensure that land is removed from non ruminants**

In the model tab in DSS, use MagnetBio_modellinkage

When the file modelchoices.har comes up, you can import the settings of the headers: CESA, CESN, ELPR, CAPP, EUTY, RPQO, FCAT, CETN (ensure that the CETN header has no pigspoultry in it since we assume that all SFP is on land), from the file, **modelsettings_modellinkage.prm**

Switch off all the headers BUDU, ACDU, SWDU and REDU

Leave all zeroes in the header EUTY

Before running the simulations….. :

In **MAGNET.tab**, which is created after the model tab step, go into the tab file and look for variable aoall(j,r). **Insert a new variable just after it called aoall2(j,r)** (also indexed over PROD_SECT and REG). **In the equation AO1, add the variable aoall2(j,r) to the end**.

This variable will be swapped with variable qos(j,r) to control for the production changes in the model. The larger are the discrepancies between what CAPRI predicts and what MAGNET predicts, then the larger will be the endogenous technical change adjustments necessary to target the CAPRI values.

Tablo check and LTG the file to generate an executable version.

In the prepare scenario tab, use Magnet_Agrifood2030_CAP_GHG_Nutrition_modellinkage

Once this step has finished, go to the folder:

4_MAGNET/Shocks/Model_linkage_keep/

Copy the pre-prepared file **shocks2007-2020.har** (this has GDP and POP shocks taken from the CAPRI model) and paste over the file of the same name in the folder:

4_MAGNET/Shocks/

In the Scenario (Gemse) tab:

Altertax run

Use answer file **MAGNET_CAP_GHG_Modellinkage_Altertax**. Once this run finishes, go to the folder 4_MAGNET/Updates and copy the file:

MAGNET_CAP_GHG_Modellinkage_Altertax_2007-2020_update.har

Into the folder 4_MAGNET/Basedata and overwrite the file basedata_b.har

GDP Exo run

Use the answer file **BaseGDPExo_modellinkage**

CAP Baseline run #1

This baseline run does not employ any linked shocks on output from the CAPRI model, but simply generates MAGNET results using CAPRI GDP and POP shocks and aland shocks from MAGNET (SSP2).

To run this scenario, use the answer file **baseGDP_Modellinkage_CAPBaseline**. This includes the shocks file **macroshocks_modellinkage.cmf** where the aknreg shocks are read from the solution file (*.sol) of the GDPExo run. This is done, because the initial shocks2007-2020.har file was overwritten using GDP and POP shocks from CAPRI (the final shocks2007-2020.har used is not generated in the **prepare scenario tab step.** For practical reasons, this makes no difference at all to the running of the model (i.e., the results).

Solution files are BaseGDP_Modellinkage_CAPBaseline_2007-2020_Solution.sl4/slc/sol

CAP Baseline run #2

This baseline run includes linked shocks on agri-food output from the CAPRI model, as well as CAPRI GDP and POP shocks and aland shocks from MAGNET (SSP2).

To run this scenario, use the answer file **baseGDP_Modellinkage_CAPBaseline_CAPRI**. This includes the shocks file **macroshocks_modellinkage_CAPRI.cmf** where the aknreg shocks are read from the solution file (*.sol) of the GDPExo run and the output shocks for the agrifood sectors are read from the file

KJ-NA-28625-EN-N

JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

EU Science Hub
ec.europa.eu/jrc

@EU_ScienceHub

EU Science Hub - Joint Research Centre

Joint Research Centre

EU Science Hub

Publications Office

doi:10.2760/712139
ISBN 978-92-79-69101-0