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EU import restrictions on genetically modified feeds: impacts on Spanish, EU and global livestock sectors

G. Philippidis*

Aragonese Agency for Research and Development (ARAID).
Government of Aragón. Avda. Montañana, 930. 50059 Zaragoza. Spain

Abstract

Over the last decade, much controversy has surrounded the usage of genetically modified organism (GMO) technology in commercial agriculture. More specifically, it is feared that GMOs may introduce new allergens into the food chain or contribute to antibiotic resistance. At the current time, the European Union (EU) adopts a zero tolerance policy toward «non-approved» GMO imports, whilst the approval process has not kept pace with the proliferation of new GMO varieties. In the EU livestock sectors, this apparent mis-match threatens to interrupt supplies of high protein feed inputs (*e.g.,* soymeal) from countries with more relaxed regulations regarding GMOs. Employing a well known multi-region computable general equilibrium framework, this study quantitatively assesses the impact of a hypothetical EU import ban on unapproved GMO varieties of soybean and maize imports on livestock, meat and dairy sectors. The model code is heavily modified to improve the characterisation of the agricultural sectors and land usage, whilst a realistic baseline is employed to update the global database to 2008, the year the hypothetical ban is implemented. In the «worst case» scenario, there are significant competitive losses in EU livestock, meat and dairy sectors. In Spain, the negative impacts are particularly pronounced given the importance of pig production in agriculture. In contrast, all non-EU regions' trade balances improve, with notable trade gains in the USA and Brazil. To conclude, the EU must urgently find a long term strategy for GMOs if it is to reconcile political expediency with pragmatic economic concerns.

Additional key words: computable general equilibrium, global trade analysis project.

Resumen

Las restricciones sobre importaciones europeas de los OMGs: impacto sobre los sectores ganaderos españoles, europeos y mundiales

El uso de organismos genéticamente modificados (OMGs) en los sectores agro-ganaderos ha desatado mucha polémica. En particular, se teme que puedan introducir nuevos alérgenos dentro de la cadena agroalimentaria, o subir el nivel de tolerancia hacia los antibióticos. Actualmente, la Unión Europea (UE) aplica tolerancia cero hacia las importaciones de OMGs «no-aprobados», aunque la tasa de aprobación no se mantiene en paridad con la proliferación de nuevas variantes de OMGs. En la UE, este desajuste podría interrumpir los suministros de piensos con alto contenido proteico desde los países que aceptan el uso de OMGs. En este estudio se emplea un modelo de equilibrio general computable mundial, para analizar el impacto de una prohibición hipotética de las importaciones de soja y maíz transgénicos no-aprobados sobre los sectores ganaderos con orientación cárnica y láctea. Se modifica intensamente el modelo para reflejar con más precisión el sector agrario y el uso de la tierra. Además, se emplea un «baseline» realista para actualizar la economía global hasta 2008, año en que se implanta la prohibición. En el peor escenario planteado, se dan pérdidas grandes en los sectores ganaderos, tanto de carne como de leche, en la UE, mientras en España el impacto es peor debido a la importancia del sector de porcino. En contraste, terceros países experimentan ganancias en sus balanzas comerciales, especialmente EEUU y Brasil. En conclusión, la UE debe adoptar una estrategia sobre los OMGs para reconciliar las amenazas económicas potenciales sobre los sectores ganaderos con las preocupaciones sanitarias.

Palabras claves adicionales: modelos de equilibrio general computable, proyecto de análisis del comercio global.

* Corresponding author: gphilippidis@aragon.es
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Abbreviations used: CGE (computable general equilibrium), DEFRA (Department of Environment, Food and Rural Affairs, UK), EU (European Union), GMO (genetically modified organism), GTAP (Global Trade Analysis Project), MTR (mid term review), ROW (rest of the world), RPI (retail price index), CES (constant elasticity of substitution), CET (constant elasticity of transformation), SFP (single farm payment), AusNZ (Australia and New Zealand), RussiaFSB (Russia and Former Soviet Bloc), EU3 (Austria, Netherlands, Sweden), AC2 (Bulgaria and Romania), EU15 (European Union 15 members), EU27 (European Union 27 members), EC (European Commission), MARM (Ministerio de Medio Ambiente y Medio Rural y Marino, Madrid), USDA (United States Department of Agriculture).

Introduction

With the advent of biotechnology and its perceived competitive advantages to commercial agriculture, there has been a rapid proliferation and usage of genetically modified organisms (GMOs) over the last 10 years. In contrast, European Union (EU) enthusiasm for GMOs has been seriously hampered by scientific concerns relating to the possible long term impacts on the food chain and ultimately consumer health and safety issues. At the current time, the EU adopts a zero tolerance policy toward non-approved GMO imports, where if trace levels of GMO are found, the whole shipment is refused entry[1].

To further complicate matters, the authorisation process in the EU has so far failed to keep pace with the speed with which new strains of GMO crops are being adopted and accepted in non-EU regions. There are currently 70 GMOs for maize (*Zea mays* L.), rape (*Brassica napus* L.) and soybean (*Glycine max* (L.) Merr.) in the approval pipeline, which is expected to increase to 100 in the next two years (Cardy-Brown, 2008). More discouragingly, there appears to be little consensus amongst member states, or a clear long term EU strategy regarding GMO usage (EurActiv.com, 2009b).

This uncertainty casts a long shadow over the EU livestock sectors which heavily depend on feed imports. For example, last year the new strain of RoundUp Ready 2 soybeans which was ready for planting in the US, threatened EU animal feed security until an eleventh hour agreement was approved by the Commission. Furthermore, imported substitutes for oilseed meal (particularly soybean) and other protein-rich feedstuffs at the quantities required are only available from limited sources, with over 90% of EU soybean imports originating from Argentina, Brazil and the USA.

Owing to climatic and agronomic factors, there is no viable prospect for developing EU production of protein rich plants at short notice. Even stepping up the production of substitute protein crops such as field peas, field beans and sweet lupines as alternatives for soybean, would still leave a shortfall in meeting EU demand requirements. In the past, the EU's position was protected by its status as a key customer market, however, the emergence of large importers such as India and China, both of which employ more liberal regimes with respect to acceptance of GMOs, threatens to reduce the EU's leverage over supplier countries.

The aim of this study is to quantitatively assess the impact on EU livestock, meat and dairy sectors from a hypothetical EU import ban on unapproved GMO varieties of soybean and maize imports from one or more of the major suppliers (Argentina, Brazil and the USA). As a basis, the Global Trade Analysis Project (GTAP) database (version 6) (Dimaranan, 2006) is employed, covering 87 regions and 57 commodities. To achieve this aim, the accompanying computable general equilibrium (CGE) model has been heavily modified to incorporate explicit modelling of agricultural factor, input and output markets, whilst a realistic baseline updates the global database to 2008, the year the hypothetical ban is implemented. Further to the above, the import bans are modelled using a novel approach, whilst the impact of global bio-fuels production on competing land usage is also characterised in an attempt to improve the credibility of the model estimates.

Methods

GTAP (Hertel, 1997) is a «demand» led model, based on a system of neoclassical final, intermediate and primary demand functions. Given the assumption of weak homothetic separability, optimisation is broken into nests to allow greater flexibility through the incorporation of differing elasticities of substitution, whilst accounting identities and market clearing equations ensure a general equilibrium solution. Once the model structure is calibrated to the chosen data aggregation, specific exogenous macroeconomic or trade policy «shocks» can be imposed to key policy variables (*i.e.,* changes to tax/subsidy rates, factor endowments, technical change variables etc.). The model responds with the interaction of economic agents within each market, where an outcome is characterised by a «counterfactual» set of equilibrium conditions. In this study, the standard framework is modified in a number of ways. All modifications and relevant mathematical derivations are discussed in the technical appendix.

[1] Given the chemical difficulty in preventing the accidental presence of GMOs in conventional seeds, there has been some debate within the EU on acceptable levels of tolerance. While most member states apply the zero tolerance principle, the levels accepted are 0.1% in France, 0.5% in the UK and 0.9% in Romania (EurActiv.Com, 2009a).

Model modifications-agricultural factor, input and output markets

Following the work on GTAP-AGR by Keeney and Hertel (2005), constant elasticity of substitution (CES) possibilities are modelled between intermediate inputs and primary factor demands, whilst in livestock sectors, intermediate feed inputs are also now CES substitutable[2]. A constant elasticity of transformation (CET) controls the transfer of labour and capital factors between agricultural/non-agricultural sectors to capture observed differentials in wages and rents in each sub-sector.

Other modifications include the incorporation of a three-stage weakly separable CET nest to capture land heterogeneity across different agricultural activities. In addition, following Tabeau *et al.* (2006), an endogenous non linear land supply function is econometrically estimated, whilst in the EU regions, additional model code is inserted to enforce an upper limit to the registered agricultural land area upon which the single farm payment (SFP) is based. Employing recent developments in the literature, the study also incorporates an explicit representation of the EU's CAP (*e.g.*, set aside, CAP budget, intervention prices, quotas, etc.), which constitutes an important component of our «baseline» scenario.

Modelling an import ban

In this study, a novel method for modelling an import ban is proposed. More specifically, with reduced confidence in feed imports (due to food safety fears), there is a reduction in associated utility corresponding to that bilateral route, which in turn motivates import reductions. Employing cost minimisation and expressing in percentage changes (denoted by lowercase letters) gives:

$$q_{i,r,s} = u_{i,s} - \sigma_i [p_{i,r,s} - p_{i,s}] + \sigma_i z_{i,r,s} \qquad [1]$$

Linearised Hicksian import demands of commodity «i» from region «r» to import region «s» ($q_{i,r,s}$) are a function of commodity prices ($p_{i,r,s}$), utility ($u_{i,s}$), the utility scaling variable ($z_{i,r,s}$) and the elasticity of substitution parameter (σ_i). Implementation of the import prohibition, characterised as a downturn in «confidence» for EU feed imports, is captured by swapping the scaling variable (z) with import demands (q).

The inclusion of bio fuels in the GTAP data and model

In the baseline, recent increases in bio-fuel production are characterised to recognise its impact as a form of competing land usage, particularly in the USA and Brazil. This study draws on two studies by Taheripour *et al.* (2008) and Birur *et al.* (2008) respectively. Taheripour *et al.* (2008) include additional bio-fuels activities (bio-diesel; grain based bio-ethanol; cane base bio-ethanol) to the GTAP database by splitting them out of existing sectors. A perceived advantage is that the database better characterises changing patterns of land usage (particularly in Brazil and the US) from rapid bio-fuels expansion. Since bio-fuels are directly substitutable with petrol at the pump, following Birur *et al.* (2008), adjustments are made to the GTAP private demand structure to characterise «demand driven» increases in bio-fuels production from increases in crude oil prices. Further discussion of the incorporation of biofuels into the model is given in part IV of the technical appendix.

Data aggregation

The choice of model aggregation is detailed in Figure 1. All primary agricultural sectors are disaggregated

24 Sectors: rice, wheat, other grains, vegetables fruits and nuts, oilseeds, raw sugar, other crops, cattle/sheep, pigs/poultry, raw milk, wool, red meat, white meat, dairy, other food processing, beverages and tobacco, energy (gas, coal, electricity), bio diesel, bio ethanol (cereals and cane based), crude oil, refined petroleum, manufacturing; services.

19 Regions: France, Germany, UK, Spain, EU3 (Austria, Netherlands, Sweden); Rest of EU15, Accession 10[1], Accession 2[2], RussiaFSB (Russia and Former Soviet Bloc), Turkey, USA, Canada, Argentina, Brazil, RoLatAme (Rest of Latin America), Australia & New Zealand, China, India, ROW[3].

Figure 1. GTAP data aggregation. [1] AC10: Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia. [2] AC2: Bulgaria, Romania. [3] ROW: rest of the world.

[2] The standard GTAP employs a Leontief specification. This implies that, for example, the intensiveness of fertiliser application on land cannot alter, or competing feeds are not substitutable in livestock sectors. Substitution elasticities are calibrated to OECD central values of Allen partial elasticities (Keeney and Hertel, 2005).

including the three livestock sectors of cattle/sheep, pigs/poultry and raw milk. In the food processing sectors, red and white meat sectors and dairy are disaggregated to capture the impacts of increasing feed costs in these downstream sectors. The «new» bio-fuels sectors are disaggregated along with an energy composite (gas, coal, electricity), crude oil and petroleum. The remaining sectors are captured within the composites of manufacturing and services. The EU consists of the «big-three» (France, Germany, UK), Spain (major EU pork producer) and four composite EU regions[3]. The non EU regions consist of the main suppliers of maize and soybean to EU27 markets (Argentina, Brazil, USA). In addition, «large» agricultural players (*e.g.*, AusNZ[4], Canada, China, India) on world markets as well as other potentially important EU trade partners (*e.g.*, RussiaFSB[5], Turkey) are featured.

Scenario design

In the first part of this experiment a baseline scenario is run (see Fig. 2) to capture the main trade policy drivers which have occurred since the benchmark year of 2001. Macro projections data between 2001 and 2020 on GDP, endowments and productivity are taken from Walmsley (2006). The shocks between 2001 and 2008 are calculated and aggregated to the 19 GTAP regions employed in this study. Importantly, all tariff shocks account the tariff overhang between the bound and applied tariff rates, employing the work of Jean *et al*. (2005). In addition, the 2003 Mid Term Review (MTR) CAP reforms are implemented. Finally, to capture the increased importance of bio-fuels in global land usage, a shock to the world price of crude oil is implemented which corresponds to the price rise between 2001 and 2008.

The updated 2008 data are subsequently employed as the benchmark data in the policy scenarios. In the study, three scenarios are examined:

1. No imports of GM soybean meal and maize from the US to the EU.
2. No imports of GM soybean meal and maize from Argentina and the US to the EU.

Baseline assumptions

1. Uruguay Round Commitments (+)
   - Enforce developed country commitments (export subsidy limits, applied tariff levels).
   - Complete developing country commitments (export subsidy limits, applied tariff levels).
2. EU enlargement to 27 members (+)
   - Remove border protection between existing and «new» member states.
   - Impose common external tariff for all new EU members of the customs union.
3. Additional trade policy shocks (+)
   - Chinese Accession.
4. Agenda 2000 (A2000) commitments and the mid term review (MTR)
   - Modelling of CAP mechanisms (CAP budget, modulation, quotas, set-aside, intervention prices).
   - Reduction of intervention prices under A2000 and MTR reforms.
   - Removal of ALL coupled support in the AC12 and MTR agreed components of coupled support (#) in the EU15.
   - CAP budget including the implementation of modulation funding and the UK rebate mechanism.
   - Full implementation of the SFP and land idling shocks.
5. Crude oil price shock of 166%
6. Update shocks (2001-2008) (–)
   - Shocks to GDP, factor endowments, productivity.

Figure 2. Assumptions shaping the baseline. +: all tariff shocks account for the binding overhang. #: data taken from DEFRA. –: data taken from Walmsley (2006).

3. No imports of GM soybean meal and maize from Argentina, Brazil and the US to the EU.

In the GTAP database, soybean/soymeal and maize are subsumed within the aggregate sectors «oilseeds», «other cereals» and «other food processing»[6]. Thus, the relevant import reductions in these GTAP sectors are based on the average proportion of the affected crops within each sector. To acquire this information, data were solicited from the UN COMTRADE (2008) database for a series of recent years (2001-2007) and averages were calculated. For example, referring to Table 1, the required negative shock to imports to remove non approved maize and soybean/soymeal from the «other food processing» sector on exports from Argentina to Spain is –42.0%.

[3] Due to the modelling of the CAP budget, the EU3 (Austria, Netherlands, Sweden) must be separated from other EU regions.
[4] Australia and New Zealand.
[5] Russia and Former Soviet Bloc.
[6] «Prepared animal feeds» appear in the «other food processing» sector. For information on the GTAP concordance with specific disaggregate sectors, see Dimaranan (2006).

Table 1. EU trade share data in percentage (2001-2007 average)

Regions[1]	Share of «maize» in «other cereals»			Share of «soybean» in «oilseeds» imports			Share of soyben/maize feed in «other food processing»		
	Arg[2]	Bra[3]	USA[4]	Arg	Bra	USA	Arg	Bra	USA
UK	98.0	43.4	3.3	6.7	96.5	53.8	17.7	32.7	0.8
EU3	86.1	51.3	17.4	8.8	99.1	88.8	50.5	20.2	1.2
Ger	13.4	23.9	5.5	24.4	99.7	93.5	27.1	18.4	0.2
Fra	70.0	50.0	49.4	2.3	99.3	77.4	32.1	69.5	0.7
Spa	97.6	92.5	23.4	30.2	99.5	85.5	42.0	15.6	1.1
Ro15	92.5	55.4	27.0	64.3	99.5	87.2	59.8	23.8	2.9
AC10	53.2	74.3	67.9	5.1	47.4	15.5	56.3	41.3	4.2
AC2	63.8	74.6	72.3	24.3	50.0	38.6	39.8	12.2	2.0

[1] See Figure 1. [2] Argentina. [3] Brazil. [4] United States of America. *Source:* UN COMTRADE (2008) and own calculations.

In addition to the import shocks, estimates of increases in feed costs are also implemented into the EU livestock sectors. In CGE models, multistage budgeting compartmentalises input and factor demands into nests, each with an individual elasticity of substitution. Consequently, when faced with supply constraints, CGE models have a tendency to «substitute around» problems, thereby mitigating the impacts on product markets. For example, imported animal feed inputs are largely constrained to the sector «other food processing», whilst the corresponding cost share is small[7]. Thus, with an elimination of non-approved maize and soybean related feed imports and substitution possibilities in favour of cheaper «domestic» equivalents, the total cost impact in livestock sectors is unrealistically moderate. An immediate response would be to assume Leontief (*i.e.,* zero) substitution technology (or something very close to zero) in the livestock sectors. Unfortunately, this assumption would affect the substitutability of *all* animal feed inputs (domestic and imported), which is hard to justify in policy terms. To reinforce the point further, if imported soybean usage by pigs/poultry in Spain fell by 50%, by virtue of the Leontief assumption, one would be imposing the restriction that all inputs, and therefore outputs, would also be falling by 50%.

Accordingly, it was seen as more desirable to implement exogenous estimates of average feed cost rises from the loss of (primarily) imported soybean derived feeds[8]. This approach captures the «essential» nature of non-substitutable feeds without purging the essential substitutability which characterises input decision making in these models. Feed cost estimates will differ between livestock activities due to differing dietary requirements for soybean based feeds. To provide the animal with greater quantities of energy and protein as well as more rapid weight gain feed concentrates are needed, of which the most important are grains (maize) and oilseed meal derived from soybean. Pigs and poultry are largely fed on such feed concentrates. On the other hand, ruminant animals (cattle and sheep) can digest only certain quantities of such high concentrate feeds, whilst cheap «on-farm» (*i.e.*, pasture based) sources of forage provide important sources of fibre. According to Brookes *et al*. (2005), approximately 22% of broiler feed is soybean related, whilst Cardy-Brown (2008) estimate that 22-25% of high performance pig feed is soybean based. In addition, data from FEDNA (2008) gives tables of limits for the usage of soybean ingredients in different types of Spanish livestock production, which for pork and poultry are also around 20%, whilst for cattle and sheep and dairy, the values are closer to 9% and 8% respectively.

Having approximated the cost proportion of feeds in the different livestock sectors, it is necessary to employ further assumptions to impose plausible cost rises from a hypothetical GM ban on soybean[9]. In EC

[7] Between 6-10% share in the GTAP database.

[8] In EC (2007) it is noted that the loss of maize imports from these three routes could be replaced by EU substitutes, by other domestic cereals or by imports from elsewhere. In addition, the loss of only US feed imports could conceivably be compensated by Argentina and Brazil. For this reason, the analysis does not associate feed cost rises with losses in maize, whilst in scenario 1 no feed cost rises are implemented.

[9] To implement feed cost increases, an exogenous Hicks neutral technical change variable is employed. For example, a 10% reduction on imported feeds implies that to attain the same level of feed productivity, the unit cost of imported feed inputs is now 10% higher.

Table 2. Impacts of the genetically modified organisms (GMO) import ban in the EU livestock sectors in scenario 2 (percentages)

	Fra[1]	Ger	Spa	UK	EU3	R15	AC10	AC2	EU27[2]
EU livestock feed demands									
Cattle/sheep	–1.87	–2.07	–2.23	–1.53	–3.42	–2.45	–1.80	–5.96	–2.83
Pigs/poultry	–7.00	–7.64	–7.89	–7.21	–7.74	–8.35	–8.47	–10.22	–8.16
Raw milk	–1.82	–1.79	–2.42	–1.75	–3.12	–2.14	–1.44	–5.07	–2.35
EU livestock, meat, agricultural and economic production									
Cattle/sheep	–1.37	–0.92	–2.09	–0.69	–2.24	–1.38	–1.68	–6.45	–1.92
Pigs/poultry	–8.76	–9.41	–9.74	–5.96	–8.28	–8.11	–7.70	–14.10	–9.00
Raw milk	–1.62	–1.21	–4.27	–1.00	–1.35	–2.03	–1.59	–7.83	–2.43
Agriculture	–2.00	–2.43	–3.12	–1.76	–2.49	–2.26	–2.73	–7.36	–2.99
Red meat	–0.71	–0.71	–0.53	–0.43	–1.70	–1.27	–1.08	–4.78	–1.28
White meat	–2.99	–5.49	–4.51	–2.90	–6.08	–5.79	–8.37	–5.31	–5.09
Dairy	–0.73	–0.92	–0.71	–0.53	–1.01	–1.00	–1.51	–4.71	–1.04
Real growth	–0.06	–0.04	–0.08	–0.04	–0.05	–0.03	–0.23	–1.85	–0.05
EU livestock, meat, agricultural and market price indices									
Cattle/sheep	1.18	0.63	1.62	0.92	0.76	1.01	1.44	3.14	1.31
Pigs/poultry	7.23	7.02	7.97	5.07	5.57	5.91	5.70	9.36	6.89
Raw milk	1.00	0.82	2.67	0.78	0.88	1.29	1.11	3.72	1.40
Agriculture	1.38	1.54	2.07	1.42	1.50	1.35	1.64	3.61	1.77
Red meat	0.82	0.89	0.75	0.75	0.36	1.08	0.89	1.82	0.97
White meat	3.67	4.49	4.70	3.57	4.09	4.23	4.94	3.87	4.16
Dairy	0.70	0.78	0.75	0.49	0.66	0.71	0.85	1.28	0.72
RPI[3]	0.07	0.05	0.09	0.06	0.06	0.06	0.20	0.63	0.07

[1] See Figure 1. [2] EU27: all 27 European Union members. [3] RPI: retail price index.

(2007)[10], it is estimated that average feed costs in the EU livestock sectors, from the loss of US and Argentinean soybean imports, could rise by 23%. This estimate is employed in scenario 2 for pigs/poultry, whilst proportionate average feed cost rises of 10% for cattle/sheep and 9% for raw milk production are assumed[11]. In scenario 3, EC (2007) estimate feed cost rises of 600% from the loss of Argentinean, Brazilian and US soybean imports. This percentage increase is well beyond the thresholds of the model. Consequently, a five-fold increase in feed costs compared with scenario 2 is assumed.

Results

Scenario 1

The loss of non-approved US feed imports reveals only negligible impacts in the EU27 livestock sectors, such that the results for scenario 1 are not presented. Indeed, given that the US market constitutes a minor share of EU feed imports, import substitution effects fully mitigate against any impacts in the livestock sectors. The loss of US feed to the EU is picked up (principally) by Argentinian and Brazilian exporters. In scenario 1, slightly more favourable endogenous cost changes on the part of Argentinian feed suppliers, lead to a larger proportion of EU27 feed imports from that region, although these cost driven estimates are negligible.

Scenario 2

The imposition of the GM ban on Argentinean and US imports of maize and soybean has marked repercussions on Spanish livestock sectors (Table 2). In the Spanish pigs/poultry sector, feed demands fall by

[10] This study is elaborated further in the «discussion» section.

[11] These values are based on the relative limits of soybean in the feed diets of pigs and poultry, cattle and sheep and raw milk production.

Table 3. Trade balance changes in scenario 2 (€millions)

	Cattle/sheep	Pigs/poultry	Raw milk	Red meat	White meat	Dairy
Fra	–1	–29	–1	–2	–35	–29
Ger	0	–1	0	–17	–190	–43
Spa	0	–8	0	9	–109	–10
UK	–4	–6	0	–18	–21	–15
EU3	2	–16	0	–49	–106	–11
Ro15	7	3	–1	–40	–553	–40
AC10	2	0	0	–34	–271	–37
AC2	–14	–8	–1	–23	–56	–32
EU27[1]	–8	–66	–4	–173	–1,341	–217
RusFSB[2]	0	3	0	14	76	13
Turkey	0	3	0	0	38	4
USA	6	36	0	38	304	29
Canada	3	8	0	2	92	9
Argentina	1	1	0	24	20	25
Brazil	0	1	0	12	120	–1
RoLaAm[3]	0	0	0	2	13	2
AusNZ[4]	3	8	0	16	40	50
China	0	9	0	0	135	2
India	0	1	1	2	2	1
ROW[5]	5	11	1	4	425	71

[1] EU27: all 27 European Union members. [2] RusFSB: Russia and Former Soviet Bloc. [3] RoLaAm: rest of Latin America. [4] AusNZ: Australia and New Zealand. [5] ROW: rest of the world.

7.89%, whilst in cattle/sheep and raw milk sectors, corresponding falls are estimated at 2.23% and 2.42% respectively. These estimates compare with EU27 average feed demand falls of 8.16% (pigs/poultry), 1.83% (cattle/sheep) and 2.35% (raw milk)[12]. Note that the Spanish results are relatively close to the EU27 average.

With increases in feed costs, Spanish market prices of pigs/poultry (Table 2) rise 7.97%, whilst more moderate average feed cost rises in cattle/sheep and raw milk lead to market price increases of 1.62% and 2.67% respectively. Consequently, Spanish production (Table 2) of cattle/sheep and raw milk declines –2.09% and –4.27% respectively, whilst in pigs/poultry production falls 9.74%. Comparing across the EU27, the differences in market price rises for livestock are attributed to the total cost share of feed costs in production. Equally, the transmission of prices from upstream livestock to downstream meat and dairy sectors reflects the magnitude of the livestock/raw milk cost share to the total intermediate and value added costs of meat/dairy production in the underlying input-output tables. Note that Spanish price rises in white meat production is amongst the highest in the EU27 (4.70%), resulting in a –4.51% reduction in production. With lower feed cost rises in cattle/sheep and raw milk sectors, Spanish (EU27) red meat and dairy market price estimates are notably smaller.

Given the strategic importance of the EU livestock sectors in agriculture, agricultural output (Table 2) falls by 3.12% in Spain, compared with 2.00% in France, 2.43% in Germany, 1.76% in the UK and an average EU27 fall of 2.99%. In the AC2, falls in agricultural (7.36%) and macro growth (1.85%) are considerable. The index of primary agricultural prices (Table 2) in Spain shows an increase of 2.07%, which results in a retail price index (RPI) rise of 0.09%. In the EU27, the corresponding EU27 estimates are 1.77% (agricultural price index) and 0.07% (RPI).

An examination of the trade balance impacts on EU livestock sectors from the feed ban in scenario 2 is presented in Table 3. In the GTAP database, the vast majority of «livestock» related trade occurs in the downstream processing sectors, whilst livestock trade is much smaller, especially on extra-EU trade routes. Furthermore, it is important to note that raw milk is largely non-tradable. With the fall in domestic production,

[12] The inelastic demand falls in each of the livestock sectors are determined by the elasticity of substitution parameter between feed inputs.

exports of Spanish white meat, red meat and dairy fall by 12.51%, 1.98% and 1.59% respectively (not shown), whilst cattle/sheep, pigs/poultry and raw milk exports are estimated to decrease by 3.08%, 12.10% and 14.19% respectively (not shown). Comparing with other European partners, Spanish export falls appear to be amongst the highest given the larger impacts on production. At the EU27 level, the results indicate that pigs/poultry and white meat trade could fall by between 8-9% (not shown).

With marked deteriorations in EU meat production, there is greater consumer dependency on non-EU sources of white meat, red meat and dairy products. In white meat, EU imports rise by between 10-18% (not shown), whilst in red meat and dairy, EU imports rise by magnitudes of approximately 3% and 2% respectively (not shown). In terms of the EU27 trade balances (Table 3), there are deteriorations of –€4 m (raw milk), –€8 m (cattle/sheep) and –€66 m (pigs/poultry), whilst larger base trade volumes in downstream commodities result in greater deteriorations of –€217 m (dairy), –€173 m (red meat) and –€1,341 m (white meat).

Examining the non-EU regions of the aggregation, the main exporters of red meat to the EU are Australia and New Zealand (39%), Brazil (23%), Argentina (6%), USA (6%), and the Rest of Latin America (6%). In white meat trade, Brazil has the largest trade share (19%), followed by Turkey (13%), the USA (7%), China (7%) and Australia and New Zealand (7%)[13]. Finally in dairy trade, Australia and New Zealand have a 35% trade share, followed by Turkey (16%) and RussiaFSB (9%). Non-EU regions gain at the expense of the EU, whilst lost export markets to Argentina and the USA depress feed costs, resulting in greater trade competitiveness[14].

With a relatively large trade share in EU red meat imports, USA and Argentinean red meat trade balances improve €38 m and €24 m respectively (Table 3). For the same reasons, the USA's white meat trade balance improves by €304 m (followed by China with a trade balance improvement of €135 m)[15]. Given the size of their initial trade share, Australia and New Zealand realise the largest trade surplus gains in dairy of €50 m respectively.

Table 4. Impacts of the genetically modified organisms (GMO) feed ban on world prices (percentages)

World commodity prices		Per unit world feed costs	
Impacts in scenario 2			
Cattle/sheep	0.59	Cattle/sheep	0.68
Pigs/poultry	2.25	Pigs/poultry	2.95
Raw milk	0.43	Raw milk	1.02
Red meat	0.49		
White meat	1.57		
Dairy	0.56		
Impacts in scenario 3			
Cattle/sheep	3.41	Cattle/sheep	8.93
Pigs/poultry	14.97	Pigs/poultry	25.38
Raw milk	2.19	Raw milk	6.73
Red meat	2.60		
White meat	10.05		
Dairy	2.92		

Finally, per unit world feed costs (see Table 4) are estimated to rise by 0.68%, 2.95% and 1.02% for cattle/sheep, pigs/poultry and raw milk respectively, due to the weighted increase in average EU animal feed costs. Given the transmission of feed prices into higher livestock (and eventually) meat/dairy prices, the trade weighted index of world prices in these products are also expected to rise. In scenario 2, pigs/poultry and white meat world price increases are estimated at 2.25% and 1.57% respectively. Equally, in remaining livestock, meat and dairy sectors, world prices increase by 0.59% (cattle/sheep), 0.49% (red meat), 0.43% (raw milk) and 0.56% (dairy).

Scenario 3

In scenario 3, practically all feed imports are lost, whilst feed costs are increased five-fold across all EU members. As expected, there are major impacts on livestock production (see Table 5), particularly in pigs/poultry, which has higher protein feed dependency. In Spain, pigs/poultry declines by 37.20%, compared with a corresponding contraction in EU27 pigs and poultry activity of 33.95%. As expected, cattle/sheep

[13] In the case of Turkey, this is due to poultry trade only, whilst for China, white meat trade is largely dominated by pork production.

[14] Per unit feed costs in the USA (Argentina) fall by –0.13% (–1.34) in cattle/sheep, –0.43% (–1.78%) in pigs/poultry and –0.13% (–1.46%) in raw milk production

[15] Examining the overall per capita real income change, it appears that in Argentina, increased livestock competitiveness does not compensate for lost feed sales to the EU27, such that real per capita utility falls –0.13%. In the USA, per capita utility remains static.

Table 5. Impacts of the genetically modified organisms (GMO) import ban in the EU livestock sectors in scenario 3 (percentages)

	Fra	Ger	Spa	UK	EU3	R15	AC10	AC2	EU27
EU livestock feed demands									
Cattle/sheep	–9.84	–10.58	–10.97	–7.85	–14.12	–12.04	–9.57	–14.98	–12.09
Pigs/poultry	–33.16	–33.09	–35.25	–30.56	–34.35	–33.00	–35.26	–37.87	–34.99
Raw milk	–8.50	–8.27	–10.66	–8.08	–10.32	–9.65	–6.93	–16.39	–10.37
EU livestock, meat, agricultural and economic production									
Cattle/sheep	–5.37	–3.57	–8.09	–2.51	–8.74	–5.39	–6.66	–23.99	–7.47
Pigs/poultry	–34.66	–37.01	–37.20	–25.25	–32.71	–29.90	–28.73	–45.43	–33.95
Raw milk	–6.35	–4.70	–15.56	–4.10	–5.15	–7.80	–6.41	–28.32	–9.32
Agriculture	–8.69	–10.54	–13.22	–7.86	–10.57	–9.12	–11.17	–27.60	–12.29
Red meat	–2.69	–3.10	–2.16	–2.35	–6.26	–4.68	–3.98	–15.18	–4.08
White meat	–11.57	–21.20	–18.06	–9.99	–22.17	–18.75	–25.79	–11.01	–17.60
Dairy	–2.69	–3.38	–2.59	–2.00	–3.74	–3.73	–6.10	–16.16	–3.84
Real Growth	–0.26	–0.20	–0.37	–0.16	–0.22	–0.29	–1.00	–7.88	–0.38
EU livestock, meat, agricultural and market price indices									
Cattle/sheep	6.53	3.40	8.90	5.24	4.17	5.70	8.29	20.11	7.44
Pigs/poultry	60.21	58.44	66.26	39.89	44.39	45.90	44.45	108.73	56.15
Raw milk	5.47	4.38	14.76	4.36	4.76	7.14	6.35	24.53	7.87
Agriculture	8.94	9.93	13.63	9.42	9.73	8.80	10.91	26.79	11.73
Red meat	4.32	4.64	3.96	4.41	2.16	5.70	4.64	9.26	5.18
White meat	22.92	29.48	32.59	20.41	26.20	26.68	30.26	21.28	26.14
Dairy	3.59	3.97	3.77	2.52	3.45	3.70	4.58	6.46	3.68
RPI	0.36	0.21	0.49	0.29	0.28	0.31	1.14	4.67	0.36

and raw milk production falls are more modest across EU members, leading to EU27 declines of –7.47% (cattle/sheep) and –9.32% (raw milk). Spanish agriculture contracts by 13.22%, compared with corresponding falls of –8.69% (France), 10.54% (Germany) and –7.86% (UK), whilst in the «accession 2» (Bulgaria and Romania), agriculture contracts by over a quarter. In downstream sectors, white meat production falls by –18.06% in Spain (close to the EU average), with corresponding red meat and dairy contractions of between 2-3%. In terms of macro growth, Spanish GDP contracts –0.37%; a larger reduction than other EU15 regions although considerably less than the accession 12.

As expected, EU livestock feed demands fall more dramatically then in scenario 2 (Table 5). In Spain, feed input price rises lead to pigs/poultry price rises of 66.26% (Table 5). In white meat production Spanish prices rise 32.59%, reflecting both the high pig/poultry input price rise and the its cost share in white meat production. The RPI in Spain increases 0.49% (above the EU27 average), whilst in the recent accession members, larger RPI rises reflect the greater importance of agro-food products in consumer expenditures.

With major contractions in EU27 pigs/poultry and white meat production, exports witness reductions of –51.11% and –39.44% respectively (not shown). This compares with even larger falls in corresponding Spanish sectors of –61.47% and –62.07% respectively (not shown). Examining the EU27 trade balances (Table 6), white meat worsens by –€5,991 m, whilst in red meat and dairy, corresponding trade balance deteriorations are recorded as –€996 m and –€1,058 m respectively. For Spain the trade balance deteriorations are –€42 m (red meat), –€722 m (white meat) and –43 m (dairy).

As in scenario 2, the loss of feed markets in Argentina, Brazil and the USA improves livestock competitiveness through cheaper feed costs[16]. The USA and Brazil realise significant improvements in their white meat trade balances of €1,135 m and €847 m respectively, whilst China (€557 m), Canada (€347 m) and

[16] In Argentina and the USA, the average feed costs falls are of a similar magnitude to scenario 2. In Brazil, per unit feed costs fall on average by 1.64% (cattle/sheep), 1.75% (pigs/poultry) and 1.64% (raw milk).

Table 6. Trade balance changes in scenario 3 (€millions)

	Cattle/sheep	Pigs/poultry	Raw milk	Red meat	White meat	Dairy
Fra	–1	–151	–3	–6	–179	–129
Ger	4	2	–2	–78	–1,320	–192
Spa	–1	–40	–1	–42	–722	–43
UK	–21	–40	–1	–110	–292	–81
EU3	11	–97	–1	–267	–615	–50
Ro15	37	–42	–6	–198	–2,279	–199
AC10	14	–2	–1	–193	–1,108	–225
AC2	–81	–60	–2	–101	524	–139
EU27	–38	–432	–18	–996	–5,991	–1,058
RusFSB	1	28	2	76	276	64
Turkey	2	11	2	1	278	20
USA	21	196	2	124	1,135	130
Canada	17	46	0	17	347	46
Argentina	1	3	0	39	56	41
Brazil	0	7	0	134	847	11
RoLaAm	0	1	0	13	65	13
AusNZ	16	50	0	105	218	257
China	1	61	0	2	557	8
India	0	9	5	10	13	6
ROW	36	95	6	16	1,941	377

Turkey (€278 m) also see notable trade balance improvements[17]. Much of the remaining EU white meat trade deficit is picked up collectively by the rest of the world composite region. In dairy trade, the largest positive gains accrue to Australia and New Zealand (€257 m) on account of its large EU trade share, whilst that of the USA also improves €130 m. Finally, with its large share of EU import markets and improved trade competitiveness, Brazil realises a red meat trade balance improvement of €134 m, followed by the USA (€124 m) and Australia and New Zealand (€105 m), with Argentina's corresponding trade balance improving €39 m[18].

Examining world price impacts in Table 4, rising costs in EU27 animal and meat production inflate trade weighted world prices by 3.41% (cattle and sheep), 14.97% (pigs and poultry) and 2.19% (raw milk), whilst in related downstream sectors, prices rise by 2.60% (red meat), 10.05% (white meat) and 2.92% (dairy). Similarly, with steep increases in EU average costs of feeds, per unit world feed costs rise by 8.93% for cattle/sheep enterprises, whilst in pigs/poultry and raw milk corresponding rises are estimated at 25.38% and 6.73% respectively.

Discussion

The study employs three scenarios to quantitatively assess the impacts from withdrawal of «non-approved» US, Argentinean and Brazilian maize and soybean feed exports to the EU. The results of the study focus on EU livestock and downstream meat and dairy sectors, whilst some discussion is reserved for non-EU markets. Scenario 1 is considered a «minimal impact» experiment, since it is envisaged that Argentina and Brazil would be able to compensate the loss of US markets. For this reason, no feed cost increases were imposed. In scenario 2 («medium impact») the combined loss of US and Argentinean supply would only be partly compensated by Brazil, resulting in exogenous feed cost increases borrowed from the literature. In scenario 3 («worst case»), there is very little compensation from the rest of the world for the loss of all three export markets, such that significant feed cost rises are implemented into EU livestock sectors. As expected, the results have alarming impacts on EU production, market prices and trade, particularly in the pigs and poultry sector which has a higher dependence of soy derivative feeds.

[17] Whilst USA feed prices fall by less than Brazil, the value of their global exports of white meat is almost three times the size of Brazil in the data. Argentina, by contrast, has a relatively small global export base of white meat in the GTAP trade data.

[18] That this gain is smaller than the USA (despite larger feed price falls in Argentina) can be attributed to the fact that USA global exports of red meat are over twelve times the magnitude of Argentina.

In a briefing document by EC (2007), the same experiments were conducted using the AgLink PE model[19]. Whilst AgLink is better placed to estimate feed costs (which have been used as inputs in the current study), unlike GTAP it does not model detailed bilateral trade relationships. Thus, there is no endogenous treatment of trade diversion between the EU members and key partner countries. Instead, import reductions in EC (2007) are modelled as exogenous reductions in aggregate EU imports. Due to this modelling difference, and the employment of the Armington assumption in GTAP[20], changes in EU import trade reported in this study are of a smaller magnitude. In terms of EU production, results are reasonably similar between studies, particularly in scenario 2, although given the 600% increase in feed costs in EC (2007), EU white meat production falls in the worst case scenario reported in EC (2007) are of greater magnitude (pigs/pork –34.7%; poultry –43.9%). An interesting result from the current study is that resulting reductions in feed costs in the US, Brazil and Argentina improves trade competitiveness in their livestock sectors, leading to noticeable trade balance improvements. For example, in the white meat sector, the trade balance improves by to €56 m (Argentina), €847 m (Brazil) and €1,135 m (USA), compared with an EU27 trade balance deterioration of €5,991 m.

Examining the case of Spain, pigs/poultry constitute almost 16% of agricultural output vis-à-vis 13% for the EU27 (MARM, 2008). This statistic concurs with the result that both agricultural and macro growth will suffer relatively more in Spain compared with other EU15 members[21]. With rapidly increasing unemployment, further redundancies from contractions in livestock, meat and dairy activities would be untenable in the current political climate. Ultimately, the likelihood of such a ban depends on the EU's importance as a customer for feed imports. In the case of the USA, the EU constitutes a minor market which explains why in the past the US has not worried about EU approval when cultivating new strains of crops (EC, 2007). The case, however, is markedly different for Argentina and Brazil, which depend heavily on EU markets for exports of feed, particularly soybean. At the current time, this partially mitigates the likelihood of the scenarios examined here, although with the rise of China and India as alternative destination markets, the EU cannot afford to be complacent.

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References

BIRUR D.K., HERTEL T.W., TYNER W., 2008. Impact of bio fuel production on world agricultural markets: a computable general equilibrium analysis. GTAP Working Paper No. 53.

BROOKES G., CRADDOCK N., KNIEL B., 2005. The global GM market: implications for the european food chain. Consultancy report Brookes West, UK, Neville Craddock Associates, UK, Biotask AG, Germany.

CARDY-BROWN CONSULTANCY, 2008. Impacts of EU Unauthorised GM's on the feed and livestock sectors. European Sherpa Group, 10th October 2008.

DIMARANAN B. (ed), 2006. Global trade assistance and production: the GTAP 6 database. Center for Global Trade Analysis, Purdue University, West Lafayette, IN, USA.

EC, 2007. Economic impact of unapproved GMOs on EU feed imports and livestock production. DG-Agri, Briefing paper.

EURACTIV.COM, 2009a. EU urged to impose GMO limits on «clean seeds», 3rd March 2009. Available in http://www.euractiv.com/en/cap/eu-urged-impose-gmo-limits-clean-seeds/article-179910. [13 July, 2009].

EURACTIV.COM, 2009b. Germany joins ranks of anti-GMO countries, 15th April 2009. Available in http://www. euractiv.com/en/cap/germany-joins-ranks-anti-gmo-countries/article-181267. [14 July, 2009].

FEDNA, 2008. Indice tablas FEDNA de ingredientes para piensos. Fundación Española para el Desarrollo de la Nutrición Animal. Available in http://www.etsia.upm.es/fedna/tablas.htm#con. [6 Dec. 2008]. [In Spanish].

GELLER H.S., 1985. Ethanol fuel from sugar cane in Brazil. Ann Rev Energ 10, 135-164.

[19] Unfortunately, only a very limited selection of results are presented from which to compare with. Moreover, estimates are confined to the EU27 composite region.

[20] Armington differentiates between products from different markets, thereby rendering each country with a degree of market power (*i.e.,* lower trade elasticities).

[21] Measured in real income terms, it is estimated that Spanish (EU27) per capita income falls 0.15% (0.10%) in scenario 2 and 0.81% (0.59%) in scenario 3.

HAAS M.J., MCALOON A.J., YEE W.C., FOGLIA T.F., 2005. A process model to estimate bio diesel production costs. Bioresource Technol 97, 671-678.

HERTEL T.W. (ed), 1997. Global trade analysis: modelling and applications. Cambridge University Press, Cambdridge, UK.

INTERNATIONAL ENERGY AGENCY, 2004. Bio fuels for transport: an international perspective. OECD Publ, Paris, France.

JEAN S., LABORDE D., MARTIN W., 2005. Consequences of alternative formulas for agricultural tariffs. In: Agricultural trade reform and the Doha development agenda (Anderson K., Martin W., eds). Ch. 4. World Bank and Palgrave MacMillan.

KEENEY R., HERTEL T., 2005. GTAP-AGR: assessing the implications of multilateral changes in agricultural policies. GTAP Tech Pap 24, Purdue University. Available in https://www.gtap.agecon.purdue.edu/resources/tech_papers.asp. [12 Jan 2009]

MARM, 2008. Anuario de Estadística Agroalimentaria. Ministerio de Medio Ambiente y Medio Rural y Marino, Madrid. Available in http://www.mapa.es/es/estadistica/pags/anuario/introduccion.htm. [1 Feb 2009]. [In Spanish].

TABEAU A., EICKHOUT B., VAN MEIJL H., 2006. Endogenous agricultural land supply: estimation and implementation in the GTAP model. 9th Annual Conference on Global Economic Analysis, Addis Ababa, Ethiopia. June 15th-17th, 2006.

TAHERIPOUR F., BIRUR D.K., HERTEL T.W., TYNER W., 2008 Introducing liquid bio fuels into the GTAP data base. GTAP Research Memorandum No. 11 2007, Updated May 1, 2008.

TIFANNY D.G., EIDMAN V.R., 2003. Factors associated with success of ethanol producers. Dept Appl Econ, Univ Minnesota, USA. Staff Paper P03-07.

UN COMTRADE, 2008. United Nations commodity trade statistics database. UN Statistics Division. Available in http://comtrade.un.org. [1 Nov 2008].

USDA, 2006. The economic feasibility of ethanol production from sugar in the United States. US Department of Agriculture, Washington, USA.

WALMSLEY, T., 2006. A baseline scenario for the dynamic GTAP model. GTAP Resource 2204. Available in https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=2204. [10 Dec 2008].

Technical appendix

Land supply estimation

In estimating land supply functions for each of the 87 member countries/regions of the GTAP database, a non linear functional form is employed:

$$Accumulated\ Area = a - \frac{b_0}{C_0 + Rent^p} \qquad [A.1]$$

where «a» is the asymptote of the function representing the maximum potential available land for agricultural purposes; b_0, C_0 and p are estimable parameters. For the econometric estimation, data on potential agricultural areas and yields developed by the International Institute for Applied System Analysis (IIASA, 2007) are employed. More specifically, yields and area data for four different levels of land suitability (4 types) across 23 crop types are available for each region (92 observations).

In an initial step, data observations are sorted in descending order of yields and the corresponding potential area is accumulated. Given the nature of data available, the «total accumulated potential area» for agricultural activity is larger than the conceptual asymptote or «maximum available (agricultural) land area» (*i.e.* the same grid-cell can be suitable for alternative crops). Accordingly, the supply function is re-scaled, assuming that the «total accumulated land area» corresponds to the actual maximum available land area (*i.e.* the distribution of the accumulated area is proportional to the distribution of the available land along the range of yields). The «maximum available land area» (or asymptote) for each country is calculated as the remaining land *excluding* bodies of water, closed forest ecosystems, other land protection schemes and land employed for housing and infrastructure.

Assuming that the most productive land is employed initially, the marginal cost of land increases, which reflects the increased conversion cost of additional units of marginal land. The rental rate of land is defined as the reciprocal of the potential yield (1/yield). All rents (yields) are normalised by dividing by the minimum rent (maximum yield) in each sample, which leads to rents above 1 and yields between 0 and 1. This scaling helps to infer the relative suitability of each country for each crop, while from an econometric standpoint it accelerates convergence to a solution.

The empirical land supply equation becomes:

$$R_Area_j = 1 - \frac{b}{C_0 + R_Rent_j^p} + \varepsilon_j \qquad [A.2]$$

where the sub-index j refers to each of the 92 observations available for each country/region; *R_Area* is the relative accumulated area for observation *j; R_Rent* is the relative land rent for observation *j; b,* C_0 and p

are parameters to estimate, with $b = b_0/a$; and finally, ε_j is the error term, which is assumed to be normally distributed, N(0,s). Eq. [A.2] is estimated by Weighted Maximum Likelihood (a suitable method for non-linear models). To improve the fit of the estimated function to the original data, higher weights are assigned to those observations with greater R_Rent_j.

The location of each country/region on its land supply curve is the use ratio (R_Area_C) of agricultural land use in 2000/2001 to maximum available land area measure discussed above. Substituting calculated land use ratio estimates (R_Area_C) into equation [A.2] and re-arranging, the «current relative rent» (R_Rent_C) is obtained. The point elasticity of the land supply function at these coordinates can then be expressed as:

$$E^S = \frac{\partial R_Area}{\partial R_Rent} \bullet \frac{R_Rent_C}{R_Area_C} = \qquad [A.3]$$

$$= \frac{\hat{b} \cdot \hat{p} \cdot R_Rent_C^{\hat{p}}}{(\hat{C}_0 + R_Rent_C^{\hat{p}})\left(\hat{C}_0 + R_Rent_C^{\hat{p}} - \hat{b}^*\right)}$$

where the circumflex over the parameters indicates the estimated coefficients[22].

In the model framework, equation [A.2] is inserted directly into the model code, where rents in the 2001 benchmark data can be calibrated given knowledge of the remaining parameters and land use ratio. To validate the correct implementation of the land supply function, calculated land supply elasticities from a simple shock must be sufficiently close to the point elasticities calculated in equation [A.3].

Other CAP modelling issues

Sugar and milk quotas are characterised employing complementarity equations in GEMPACK to allow binding/non-binding status of the quota. Estimates of milk and sugar quota rents for the EU15 in the benchmark are based on an array of literature sources and expert opinion within Defra (UK Government). To characterise **set aside** an exogenous hicks neutral productivity variable is employed. A negative shock of 10% implies that of every hectare used, only 0.9 is productive. Since the value of land in the GTAP database only reflects «productive» land, it is assumed that 2001 set aside levels are implicitly included in the benchmark data (*i.e.*, as part of the registered land area). Changes in set aside are based on projections from the European Commission.

Intervention prices are explicitly modelled employing complementarity equations. If the support price falls to the exogenous intervention price (which itself is shocked to simulate the MTR intervention price falls), stock purchases occur. Since stocks are not the result of constrained optimisation, but rather are «triggered», they must be subtracted from the regional income equation such that income remains equal to expenditure.

The decoupling of EU agricultural support is modelled by the removal of all output, intermediate input, capital and land subsidies in the GTAP database in 2001 (at different agenda 2000 rates) and replacing these with a **single farm payment (SFP)** characterised as a homogeneous land payment to all agricultural sectors. As a homogeneous land subsidy rate, the SFP does not favour any production activity (*i.e.*, no cross commodity effects) such that the payment is production neutral.

The calculation of total **modulation** savings and allocations to each EU27 region follows the Commission's proposals. Modulation savings are calculated at a 20% rate of the ceiling SFP ceiling limits. To allocate modulation funds across EU members, regional allocation shares are based on the agricultural area shares (65% weighting) and agricultural employment shares (35% weighting). This weighted estimate is subsequently corrected employing a relative GDP per capita weighting. A further constraint is imposed within the calculation to ensure that all regions receive at least 80% (as specified by the European Commission) of their initial modulation contributions (except Germany which should receive 90%). Modulation flows are incorporated within the common budget mechanism. In the 2001 benchmark, the **CAP budget** only applies to the EU15 regions. Thus, each EU region contributes to Brussels via 75% of agricultural tariff revenues and modulation, and receives funding for domestic support policies. The difference between total receipts and total contributions by each member gives a net resource cost of the CAP which is met by uniform percentage GDP contributions by each member state such that the total CAP budget balances at zero. The analysis also includes the **UK rebate mechanism**, where 66% of the UK's net contribution is refunded, whilst the remaining

[22] A full list of parameter estimates, standard errors, mean log-likelihood values, land use ratios and point elasticities for each of the 87 regions of the GTAP version six data is available from the authors on request.

EU26 fund the bill based on GDP shares. In the case of Austria, Germany, the Netherlands and Sweden, the share of the refund bill is reduced to only one quarter of their GDP share.

In terms of the **three nested CET land allocation structure**, the top nest CET elasticity is calibrated to econometric estimates of land supply to agriculture (Keeney and Hertel, 2005), which is increased by a factor of two on descending down the nest. Consequently, the mobility of land usage between agricultural sectors is reduced in comparison with the standard model (which also reduces agricultural supply responsiveness).

In the standard GTAP model, **labour and capital** are perfectly mobile, whilst in this model variant, the transference of these factors is controlled by a **CET elasticity**. The CET elasticity of transformation is calibrated to econometric central estimates of factor supply elasticities to agriculture in the literature (Keeney and Hertel, 2005). Consequently, the supply responsiveness of agricultural/non-agricultural subsectors in response to a removal of direct support in primary agriculture will be dampened compared with standard GTAP.

Modelling the import ban

Starting with the modified CES function:

$$U_{i,s} = A_{i,s}\left[\sum_r \delta_{i,r,s} Q_{i,r,s}^{-\rho_i} Z_{i,r,s}\right]^{-\frac{1}{\rho_i}} \qquad [A.4]$$

where $U_{i,s}$ is the level of sub-utility from the consumption of differentiated commodity i in region s; $Q_{i,r,s}$ is consumer demand in region s for representative variety i from region r; $Z_{i,r,s}$ is bilateral utility; $A_{i,s}$ is a scale parameter; $\delta_{i,r,s}$ is a CES share parameter; and ρ_i is an elasticity parameter. Minimising cost subject to [A.4] gives first order conditions:

$$P_{i,r,s} = \Lambda A_{i,s}\left[\sum_r \delta_{i,r,s} Q_{i,r,s}^{-\rho_i} Z_{i,r,s}\right]^{-\frac{(1+\rho)}{\rho_i}} \delta_{i,r,s} Q_{i,r,s}^{-(1+\rho_i)} Z_{i,r,s} \qquad [A.5]$$

$$U_{i,s} = A_{i,s}\left[\sum_r \delta_{i,r,s} Q_{i,r,s}^{-\rho} Z_{i,r,s}\right]^{-\frac{1}{\rho_i}} \qquad [A.6]$$

where $P_{i,r,s}$ is the price of representative varieties. Substituting [A.6] into [A.5]:

$$P_{i,r,s} = \Lambda A_{i,s}^{-\rho_i} U_{i,s}^{(1+\rho_i)} \delta_{i,r,s} Q_{i,r,s}^{-(1+\rho)} Z_{i,r,s} \qquad [A.7]$$

Linearisation of [A.6] gives:

$$u_{i,s} = \sum_r S_{i,r,s}\left[q_{i,r,s} - \frac{1}{\rho_i} z_{i,s}\right] \qquad [A.8]$$

where lower case letters are percentage changes in the corresponding upper case variables, and $z_{i,s}$ is a linearised expenditure share weighted average of bilateral utilities, with expenditure shares given as:

$$S_{i,r,s} = \frac{P_{i,r,s} Q_{i,r,s}}{\sum_r \left[P_{i,r,s} Q_{i,r,s}\right]} \qquad [A.9]$$

Linearisation of [A.7] gives:

$$p_{i,r,s} = \lambda + (1+\rho_i) u_{i,s} - (1+\rho_i) q_{i,r,s} + z_{i,r,s} \qquad [A.10]$$

where λ is a lagrangian variable. Thus, equations [A.8] and [A.10] are linearised first order conditions. Rearranging [A.10] in terms of $q_{i,r,s}$ gives:

$$q_{i,r,s} = -\sigma_i p_{i,r,s} + \sigma_i \lambda + u_{i,s} + \sigma_i z_{i,r,s} \qquad [A.11]$$

where σ_i is the elasticity of substitution between all pair-wise types of representative varieties in the nest:

$$\sigma_i = \frac{1}{1+\rho_i} \qquad [A.12]$$

Substituting [A.11] into [A.8] and rearranging in terms of $\sigma_i\lambda$ yields:

$$\sigma_i \lambda = \sigma_i \sum_r S_{i,r,s} p_{i,r,s} - \sigma_i \sum_r S_{i,r,s} z_{i,r,s} + \left[\frac{1}{\rho_i}\right] \sum_r S_{i,r,s} z_{i,r,s} \qquad [A.13]$$

Substituting [A.13] into [A.11] eliminates λ. Factorising the resulting expression gives linearised CES Hicksian primary factor demands:

$$q_{i,r,s} = u_{i,s} - \sigma_i\left[p_{i,r,s} - \left[\sum_r S_{i,r,s} p_{i,r,s}\right]\right] + \sigma_i\left[z_{i,r,s} - z_{i,s}\right] + \frac{1}{\rho_i} z_{i,s} \qquad [A.14]$$

where

$$z_{i,s} = \sum_r S_{i,r,s} z_{i,r,s} \qquad [A.15]$$

For consistent aggregation:

$$P_{i,s} U_{i,s} = \sum_r P_{i,r,s} Q_{i,r,s} \qquad [A.16]$$

By linearising [A.16], substituting [A.8] and rearranging:

$$p_{i,s} = \sum_r S_{i,r,s}\left[p_{i,r,s} + \left[\frac{1}{\rho_i}\right] z_{i,r,s}\right] \qquad [A.17]$$

Using the weighted composite hierarchical utility variable expression [A.15] and rearranging gives:

$$\sum_r S_{i,r,s} p_{i,r,s} = p_{i,s} - \left[\frac{1}{\rho_i}\right] z_{i,s} \qquad [A.18]$$

Substitution of [A.18] into [A.14], expanding the brackets and collecting terms gives:

$$q_{i,r,s} = u_{i,s} - \sigma_i[p_{i,r,s} - p_{i,s}] + \sigma_i[z_{i,r,s} - z_{i,s}] - \sigma_i\left[\frac{1}{\rho_i} z_{i,s} - \frac{\sigma_i}{\rho_i} z_{i,s}\right] \qquad [A.19]$$

Rearranging [A.12] in terms of ρ_i and substituting the result into [A.19]:

$$q_{i,r,s} = u_{i,s} - \sigma_i[p_{i,r,s} - p_{i,s}] + \sigma_i z_{i,r,s} \qquad [A.20]$$

Modified private demand structure

In Taheripour *et al.* (2008), the authors introduce three additional sectors into the standard version 6 database to capture the production of liquid bio fuels. In broad terms, these three sectors are divided into «bio diesel» from oilseeds crops (largely based in the EU); «bio ethanol» from starchy cereals crops (largely produced in the USA and to a lesser extent the EU) and «bio ethanol» based on sugar cane (mainly produced in Brazil). To avoid compromising the underlying equilibrium accounting conventions of the standard database, these three sectors are split out of existing sectors within the standard GTAP database. More specifically, the «vegetable oils and fats» sector (bio diesel), «other food processing» (bio ethanol from cereals) and the «chemicals rubber and plastics» sector (bio ethanol from cane). A perceived advantage of having three separate sectors, is that the database better characterises the different production technologies for each bio fuel output.

To estimate output levels and the intermediate input/primary factor mix for these sectors in 2001 (benchmark year), the authors draw on an array of literature sources. For estimates of production levels and trade, a report by the International Energy Agency (IEA, 2004) is employed. Similarly, assuming zero profits the value of production is divided between intermediate inputs (*i.e.,* feed stocks, chemicals, energy, other) and primary factors labour and capital employing cost component estimates from Tiffany and Eidman (2003) (cereals based ethanol), USDA (2006) and Geller (1985) (sugar cane based ethanol) and Haas *et al.* (2005) for bio diesel based on oilseeds. Due to data availability constraints, it is assumed that all inputs are produced domestically, except for the feedstock used in the bio diesel industry in the EU. It is noted that the EU imports an important portion of its oilseeds consumption, where these same trade shares are applied to the bio diesel industry imports.

Whilst this work undoubtedly represents an important step into developing the GTAP database in this direction, it is clear that the quality of this type of venture is typically restricted by both the availability and reliability of the underlying data sources. In their treatment, the authors had to assume that production processes for each of the bio fuels sectors are homogeneous across regions. Moreover, the production and trade information employed is not exhaustive and some degree of creative accounting will have been required to fill in missing gaps in the database. Finally, a lack of data restricted the possibility of representing other possible sources of bio fuels production (*i.e.*, from palm oils, sugar beet, wine).

Modifications to the private household demand nest are also included to account for bio fuel demand. Thus, in the top nest, all energy commodities are grouped into a single composite commodity within the CDE (private) function demands. The energy composite is divided into coal, oil, gas, electricity and a petroleum and bio fuels composite. Typically, energy demands are very price inelastic, which is reflected in the elasticity of substitution (ESUBPEN) value of 0.1, based on estimates in Taheripour *et al*. (2008). In the lower nest, final demands are allocated between petroleum and bio fuel products, whilst substitution elasticity estimates are taken from Taheripour *et al*. (2008). In the case of Brazil, the EU, and the USA (which dominate bio fuel production), substitution elasticities (ESUBPFU) have been calibrated to reproduce historical percentage increases in bio fuels production between 2001 and 2006 in response to increases in the price of crude oil. Thus, in Brazil, the EU, and the USA the values are 1.35, 1.65 and 3.95 respectively. As in Taheripour *et al*. (2008), in the remaining regions a default elasticity value of 2 is employed.