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Agri-food trade in GTAP-HET: Returns to scale in agriculture, and the Melitz model

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1. Introduction

Agricultural protection has frequently been among the most sensitive issues in bi- and multi-lateral trade negotiations. This is for a number of reasons, perhaps the chief of which is public concern about the long-term availability of a primary good like food which, along with certain positive cultural associations with farming, can lead to a desire to protect this domestic industry which is stronger than for other goods. Whatever the causes, the result is that there is a high demand among policy makers for analytical tools which can assess the, often complex, impacts of liberalisation on farm viability, land use change, and consumer food prices.

Since their inception, Computable General Equilibrium (CGE) models have made a rich contribution to this analysis. However, standard assumptions of constant returns to scale and perfect competition are can limit the ability of such models to answer the questions being asked by policy makers. Put simply, these questions often amount to

1. What are the opportunities:
    a) for innovative and competitive producers to increase their customer base,
    b) for consumers to benefit from increased choice and
    c) for consumers to benefit from lower food prices?
2. What are the threats:
    a) to less efficient producers from increased competition,
    b) to standards on food safety, animal welfare and the environment?

The focus of this paper is on using heterogenous firm theory in CGE modelling to improve our ability to analyse questions 1a, 1b, and 2a.

Empirical data and advances in trade theory in relation to intra-industry trade suggest that 1a and 2a can be occurring in the same country and industry at the same time, from a given degree of trade liberalisation. However, when perfect competition is assumed, this is impossible to analyse. Melitz (2003) set out a theoretical framework for monopolistically competitive markets in which trade liberalisation leads to the expansion of the most productive firms, and contraction of the least productive, and a number of authors have applied this framework to CGE modelling (see Balistreri and Rutherford (2011), Dixon, Jerie and Rimmer (2016) and Bekkers and Francois (2018) as well as Akgul, Villoria and Hertel (2016) for the GTAP-HET model itself) though none in agrifood. Combining the macroeconomic width and rigour of a CGE model with the heterogeneity of domestic farm systems represents an exciting frontier in agri-food trade policy analysis.

Section 2 of the paper outlines the key advances of heterogenous firm theory and CGE modelling, starting with a look at the key benefits, and moving on to data and parameter. requirements. Section 3 explores some issues specific to agri-food trade such as whether variable

returns to scale are present at all, and the implications of 'indirect trade' in some agricultural sectors. Section 4 presents some illustrative simulations using the GTAP-HET model (Akgul, Villoria and Hertel, 2016), and section 5 discusses the implications of the work so far, and next steps.

2. Heterogenous firm theory and CGE modelling

This section discusses the primary advantages of using a monopolistically competitive market, as opposed to perfectly competitive, market structure in CGE models, and why they are of interest to policy analysts in relation to agrifood sectors.

2.1. Firms expanding or leaving the sector

In the Melitz model, the lowering of trade barriers reduces the fixed and or variable costs of sales to one or more non-domestic market. This means that firms which were already selling to this market increase their sales. It also means that those marginal firms which were not quite efficient enough to sell in this market will be, after the cost reduction. Thus the most efficient firms (those already exporting and the most efficient of those previously selling only to the domestic market) expand.

The expansion of these firms increases demand for inputs, which pushes up the price of both factors of production and intermediate inputs used in the industry. This increases the cost of production across the industry, which pushes up the productivity threshold, and means that some of the least efficient firms exit the industry, as their variable costs now exceed their revenues.

Finally, assuming reciprocal reduction of trade barriers on imports, all of the above will apply to firms in the partner country as well, so imports from existing suppliers will expand in addition to new suppliers entering the import market.

These three effects are of interest to policy-makers principally as a result of the politically sensitivities around domestic farming and food production, but also because of the inter-depencies between farming and the natural environment. These add an additional dimension to public interest in whether and how the land is used to produce food and/or other environmental goods (or 'bads').

2.2. Endogenous productivity response

The net result of the dynamic described above, whereby the most productive firms expand and the least productive firms leave the sector, is an overall increase in average productivity in the industry as a result of trade liberalisation. Intuitively this is because more inputs are being used by high productivity firms, and fewer by low productivity firms, so the mean efficiency of input use is higher. Policy analysts have a responsibility to make clear that in this framework the model says nothing about the productivity of individual firms (which remains exogenous to the model), only average productivity of *all* the firms remaining in the industry, weighted by their production shares. Nevertheless, this is a marked advance over earlier models based on the assumption of perfect competition and a single representative firm in each industry.

In the UK, one of Defra's stated goals is to 'make [the farming sector] more prosperous and resilient, championing productive farming…' (Defra, 2018). As the UK negotiates a number of

Free Trade Agreements, the impact of these reductions to trade barriers on agri-food sector productivity will be of great interest to Ministers and policy makers.

2.3. Love of variety

In the Melitz model, consumers gain welfare from the increased choice available to them in terms of different varieties of a given commodity. The removal of trade barriers will have a mixed impact on this welfare: there will be a gain from the increase in imported varieties, but this may be (more than) offset by the loss of domestic varieties if a large number of domestic firms are leaving the sector.

Welfare gains, or losses, to consumers are clearly of interest to policy makers, but the ambiguity here is a nuance not previously available to global trade models, and hence largely unquantifiable. Whilst the numerical results should always be communicated with care, narrative insights and 'direction of travel' results on this issue could play a valuable role in filling out the picture of trade policy analysis.

3. Some issues specific to agri-food trade

3.1. Returns to scale

In the light of the above, it is important to interrogate the evidence on whether constant returns to scale in agriculture and food production is really such an unrealistic assumption after all. If the evidence were to support agri-food CRTS, then many of the arguments for a Melitz treatment of this sector would lose their potency.

There are obvious difficulties associated with measuring or recording returns to scale, as the data required is generally commercially sensitive. This generally precludes the comparison of firm-level costs relative to output, which would be the obvious method for observing the presence or absence of returns to scale. At the industry level, as the number of data points is so drastically reduced, a change of approach is needed. Fixed cost shares are seen as a reasonable indicator of returns to scale, since the lower this share is, and hence the higher the share of variable costs in total costs, the closer the costs:output relationship will be to 1:1, or constant returns to scale. Conversely, a high fixed cost share suggests a given increase in output will result in a less than proportionate increase in total costs, indicating increasing returns to scale. Unfortunately, costs are not necessarily split into 'fixed' and 'variable' in an internationally or inter-sectorally consistent manner.

3.2. Subsidies

Support for domestic agriculture in the form of payments to farmers, while not universal, is widespread, and introduces a further complicating factor into this story. In the 'traditional' Melitz model, the minimum productivity threshold is determined by the point at which revenues from sales cover the cost of production. In principle, many agricultural support payments are intended to be 'decoupled' from production, but there is some evidence to suggest that where such payments exist, in practise this is not the case. Even if payments and production were truly independent of each other though, such payments would represent a form of 'fixed benefit', as

they are only accessed by firms in the farming sector[1]. This means that arguably they should be netted out from fixed costs. Doing these calculations for every country with farm subsidies is likely to be a lengthy process, if the required data exists at all, but as a starting point, this paper presents fixed cost shares, and derives subsequent parameters, on the basis of both 'gross' and 'net' fixed costs. The former is simply fixed costs divided by total costs, although in reality even this is not that simple. The England data separates agricultural costs from other farm costs, so the agricultural costs are used here, whereas the USA does not, so overall farm costs are used. For the net fixed cost shares, in the USA this is calculated as fixed costs minus government payments, over total costs minus government payments, while in England it is fixed agricultural costs minus Basic Payment Scheme income, over total agricultural costs minus Basic Payment Scheme income.

Work ongoing, to be completed.

3.3. Indirect trade

Prehn (2012) has demonstrated the theoretical validity of the Melitz model in a sector where trade is largely conducted through intermediates, such as agriculture.

Work ongoing, to be completed.

4. Data and parameters

As well as ensuring that models remain theoretically consistent, these advances present challenges in terms of additional data/parameter requirements. The approach taken below differs from that in GTAP-HET in that the latter takes parameter estimates from the literature and uses them to derive fixed cost shares, while the purpose of this paper is to use what data there is on fixed cost shares in order to derive the necessary parameters. Nevertheless, the GTAP-HET parameters for the manufacturing aggregates TransMachEq and HeavyMnfc offer useful points of comparison for the estimates derived below. Note that the order of this section follows that of our process, from data to parameters.

4.1. Fixed and variable cost shares

The gross and net fixed cost shares by farm type for the USA and England are presented in Figures 1 and 2, along with those derived in GTAP-HET for comparison. The general picture is that fixed cost shares tend to be higher in England than in the USA, and that they tend to be higher in crops than in livestock, though this last is more noticeable in the USA than in England.

More to follow.

4.2. Elasticity of substitution between varieties

This elasticity of substitution, usually represented as σ, measures the degree of substitutability between different varieties of a given commodity. Where σ is high, varieties are highly substitutable, suggesting they are relatively homogenous. Where σ is low, there is little substitution between varieties, suggesting they are very different from each other.

[1] Indeed, sometimes only certain types of farming. The point is though, that there is usually some conditionality to ensure such payments go to 'active farmers', making them effectively equivalent (but opposite) to a fixed cost of entering the industry.

Akgul et al. (2016) use elasticity estimates from other sources to derive the share of fixed costs in total costs as $1/\sigma$. Tables 1 and 2 use the fixed cost shares described above to reverse this process, and estimate σ for the USA and England respectively, by farm type. The distinction between 'net' and 'gross' fixed costs is explained in 3.2. above.

Work on elasticity estimation is ongoing. More to follow.

4.3. Shape parameter for productivity distribution of firms

It has become common to assume a Pareto distribution of firm productivity, with the highest number of firms operating only just above the minimum productivity 'cut-off point' needed to sell in domestic markets, and the number of firms decreasing as productivity increases, with a very small number of high productivity firms. This function requires a cut-off point (the minimum productivity level required to operate in the domestic market), and a shape parameter. The former is determined by costs and prices in the model, but the shape parameter must be set exogenously.

Work on shape parameter estimation is ongoing. More to follow.

4.4. Industry mark-up

The mark-up in a monopolistically competitive industry is ratio of the price firms can charge, relative to their cost of production. Note that in a perfectly competitive industry this ratio is 1. GTAP-HET calculates the mark-up as $\sigma_i/(\sigma_i - 1)$ (Akgul et al., 2016), and on this basis, estimates for the mark-up ration are presented in tables 3 and 4. Some of the numbers for farm types in England look suspiciously high, with cereals, general cropping and lowland livestock all having ratios of two or over when gross fixed costs are used, while the highest ratio for the USA is corn at 1.53.

Work on markup estimation is ongoing. More to follow.

4.5. Fixed trade costs

Akgul et al. (2016) derive the following means of separating total fixed costs into those which are associated with specific trade routes, and 'set-up' costs to operating in the domestic market. They show that for any given trade route the former is equal to

$$Sales_{i,r,s} * [\gamma_i - \sigma_i + 1]/[\gamma_i * \sigma_i]$$

with set-up costs accounting for all fixed costs which are not allocated to a specific export route (of good i from region r to region s) by this method.

Work on fixed trade costs estimation is ongoing. More to follow.

5. Testing parameters using GTAP-HET

Work ongoing, to be completed.

6. Discussion and implications

Work ongoing, to be completed.

Tables and Figures

Table 1: Sigma estimates from fixed cost shares - USA

USDA	σ 1 (net fixed costs)	σ 2 (gross fixed costs)
All farms	7.4	5.1
Wheat	5.6	3.8
Corn	5.4	3.0
Soybean	18.9	3.4
General cash grains	12.4	3.7
Tobacco, cotton, peanuts	24.8	5.0
Fruit, veg, nuts	8.1	7.7
Other field crops	6.7	4.3
Cattle	8.1	6.2
Hogs	7.9	6.3
Poultry	7.5	6.9
Dairy	12.3	9.4
Other livestock	7.1	6.0

Table 2: Sigma estimates from fixed cost shares - England

England	σ 1 (net fixed costs)	σ 2 (gross fixed costs)
Horticulture	2.5	2.3
Specialist pigs	2.9	3.1
General cropping	2.9	1.9
Mixed	3.3	2.0
Dairy	3.0	2.6
Cereals	3.8	1.8
Specialist poultry	3.9	3.1
Lowland livestock	5.0	2.0
Less Favoured Area livestock	19.4	2.1
All farms	2.2	3.4

Table 3: Mark-up ratio estimates - USA

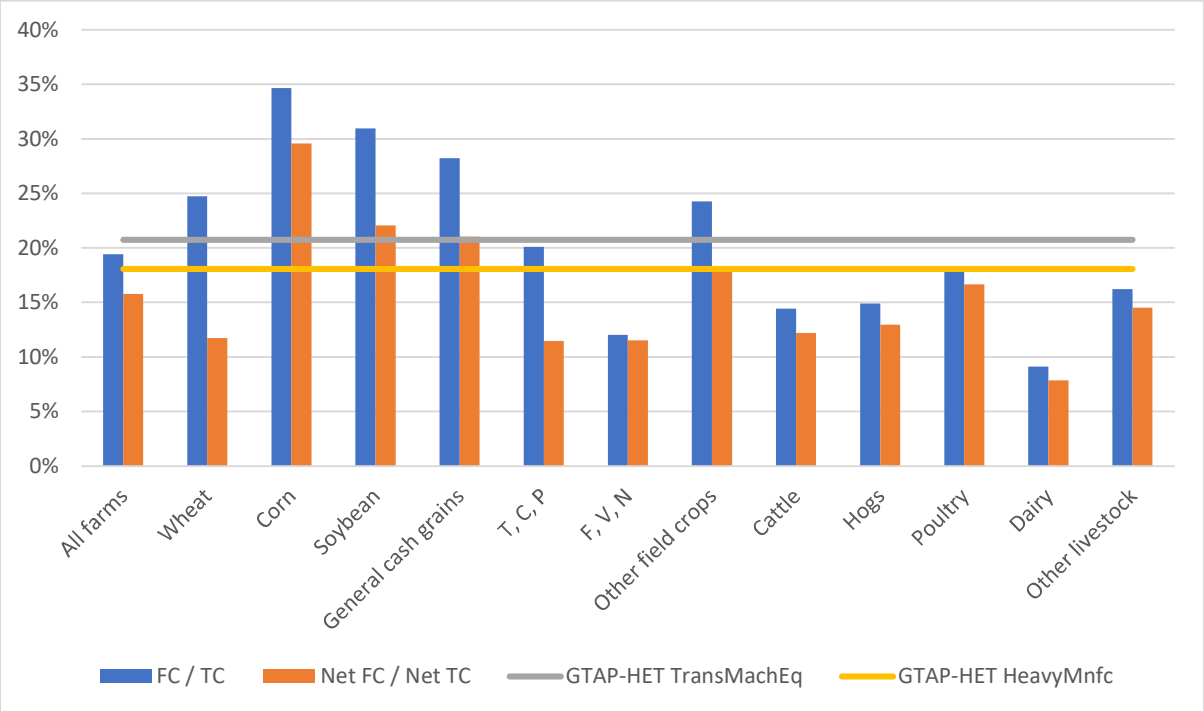
USDA	net fixed costs	σ 2 gross fixed costs
All farms	1.19	1.24
Wheat	1.13	1.33
Corn	1.42	1.53
Soybean	1.28	1.45
General cash grains	1.27	1.39
Tobacco, cotton, peanuts	1.13	1.25
Fruit, veg, nuts	1.13	1.14
Other field crops	1.22	1.32
Cattle	1.14	1.17

Hogs	1.15	1.17
Poultry	1.20	1.22
Dairy	1.09	1.10
Other livestock	1.17	1.19

Table 4: Mark-up ratio estimates - England

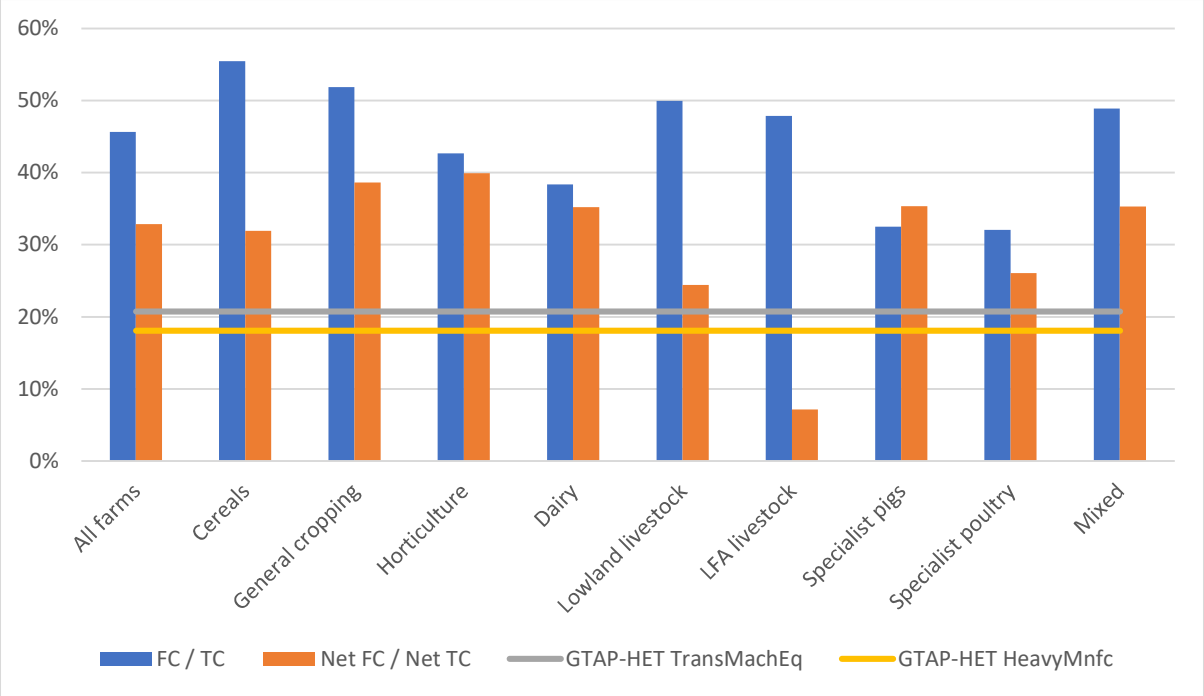
England	net fixed costs	gross fixed costs
Horticulture	1.74	1.66
Specialist pigs	1.48	1.55
General cropping	2.08	1.63
Mixed	1.96	1.55
Dairy	1.62	1.54
Cereals	2.25	1.47
Specialist poultry	1.47	1.35
Lowland livestock	2.00	1.32
Less Favoured Area livestock	1.92	1.08
All farms	1.84	1.49

Figure 1. Fixed cost shares of US farms, 2017-2019



Source: USDA Farm Business Income Statement

Figure 2: Fixed cost shares of England farms, 2017-2019



Source: Defra Farm Accounts England

References

Akgul, Z., N.B Villoria and T.W. Hertel, 2016, "GTAP-HET: Introducing Firm Heterogeneity into the GTAP Model", *Journal of Global Economic Analysis,* 1, 111-180.

Balistreri, E.J. and T.F. Rutherford, 2013, "Computing General Equilibrium Theories of Monopolistic Competition and Heterogenous Firms", in *Handbook of Computable General Equilibrium Modelling,* P.B. Dixon and D. Jorgenson eds., Elsevier.

Bekkers, E. and J. Francois, 2018, "A Parsimonious Approach to Incorporate Firm Heterogeneity in CGE-Models", *Journal of Global Economic Analysis,* 3, 1-68.

Defra, 2018, 'Defra group's strategy: creating a great place for living' https://www.gov.uk/government/publications/defra-groups-strategy-creating-a-great-place-for-living

Dixon, P.B., M. Jerie and M.T. Rimmer, 2016, "Modern Trade Theory for CGE Modelling: the Armington, Krugman and Melitz Models," *Journal of Global Economic Analysis,* 1, 1-110.

Krugman, P.R. 1980, "Scale Economies, Product Differentiation, and the Pattern of Trade," *American Economic Review,* 70, 950-959.

Melitz, Marc J. 2003, "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica,* 71, 1695-1725.

Prehn, S. 2012, "Agriculture and New New Trade Theory, Theoretical, Methodological and Empirical Issues," Ph.D Thesis, Universität Göttingen.