Grated cheese: Joint production and dairy disaggregation in computable general equilibrium

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Abstract

We consider joint production and disaggregation in the dairy sector by specifying a disaggregation routine that nests a standard Global Trade Analysis Project (GTAP) model and a model built on a SplitCom disaggregation as special cases. We show that disaggregation and joint production can have a large influence on simulation results. In a detailed application, we consider the removal of US tariffs on New Zealand dairy products. Disaggregation of the dairy sector results in a welfare gain nearly twice as large as when dairy products are included in a single sector. Our preferred aggregation and production specification for dairy commodities generates results that differ from those produced by standard approaches.

Key words: Disaggregation, joint production, computable general equilibrium modelling

JEL codes: F18, D58

Disclaimer

The views expressed in this paper are those of the authors and do not necessarily reflect the views of the Ministry of Foreign Affairs and Trade.

Introduction

Computable general equilibrium (CGE) models are useful, and increasingly popular, because they allow the evaluation of the market and welfare impacts of different trade negotiation outcomes. The models have therefore created a strong niche for themselves in advocating the benefits of trade liberalisation. But most CGE models, including the Global Trade Analysis Project (GTAP) model, can suffer from serious aggregation issues due to product level data constraints. This problem is particularly acute when a region's exports are dominated by a sector (or sectors) that has not received the same degree of disaggregation in the global database as major export sectors in other regions.

Several recent projects have addressed aggregation issues. Horridge (2005) documents a utility, SplitCom, that facilitates disaggregation of GTAP sectors into several components. The program requires the user to input cost shares or splitting shares for disaggregated commodities. Mraz and Mathews (2007) facilitate the use of SplitCom for dairy disaggregation by estimating production cost shares for four dairy commodities in 14 regions. Grant *et al.* (2007 & 2008), on the other hand, conduct a CGE tariff line analyses of US dairy protection and identify 24 dairy sub-sectors. We complement this literature by focusing on joint production in a disaggregated dairy sector. Models built on a SplitCom disaggregation do not take into account potentially important dairy production features. For example fat and protein are produced jointly (i.e., protein is produced by extracting fat from raw milk). Consequently, if the dairy sector is divided into protein-based (e.g., skim milk powder) and fat-based products (e.g., butter), a SplitCom disaggregation may result in unrealistic liberalisation-induced production changes.

We analyse the impact of disaggregation using SplitCom by specifying a disaggregation routine that nests GTAP's standard aggregation and a SplitCom disaggregation as special cases. We do this using a constant elasticity of transformation (CET) function to allocate a sector's output to alternative sub-sectors and varying the CET parameter and the elasticity of substitution between disaggregated commodities in demand. Grant *et al.* (2007 & 2008) also use a CET function to allocate dairy production across alternative commodities. These authors, however, assume that transformation possibilities across alternative commodities are equal. In contrast, we allow transformation possibilities between different dairy commodities to differ using a nested CET specification.

Our analysis focuses on New Zealand dairy production as dairy products account for a significant proportion of New Zealand's total exports and several commodities in this sector require joint production. Distortions in this sector are also relatively large, so production responses following trade liberalisation are likely to be sizeable. We first tease out the important features of different aggregation routines in an illustrative setting and then turn our attention to a detailed analysis of the removal of US dairy tariffs on products from New Zealand. Our routine can be applied to a subset of GTAP regions and requires a modest amount of additional data. Supplementary data requirements include (a) output by sub-sector, (b) bilateral exports from the region(s) of interest to destinations of interest, and (c) trade distortions relating to the region of interest.

This paper has three further sections. Section 2 outlines our disaggreagtion procedure and details results from our illustrative simulations. Section 3 discusses the form of our detailed analysis and reports modelling results. Section 4 concludes.

2. Disaggregation and illustrative analysis

We outline our disaggregation procedure and highlight how alternative specifications influence modelling results using a highly aggregated version of the 'GTAP6inGAMS' model that focuses on New Zealand. New Zealand is an interesting case as dairy exports make up around 16% of this nations total exports.[1] GTAP6inGAMS draws on version 6 of the GTAP database and is programmed using the General Algebraic Modelling System (GAMS) programming language. Rutherford (2005) discusses the model in detail. Our illustrative analysis identifies two regions (New Zealand and the Rest of World) and five sectors (dairy products, other agriculture, resource-based sectors, manufacturing, and services).

We disaggregate GTAP's dairy sector into two commodities, butter (fat-based) and skim milk powder (SMP, protein-based). New Zealand dairy production in our

[1] Uruguay's dairy exports contribute 4% of this total exports, which is the second-highest dairy export share across all regions included in the GTAP database.

illustrative analysis is outlined in Figure 1. Dairy output is distributed across butter and SMP production according to a CET function. Transformation between dairy commodities is controlled by elasticity parameter σ^T. Tariffs and transport costs are applied to the disaggregated commodities. Dairy commodities are combined using a constant elasticity of substitution (CES) function with elasticity parameter σ^S. The composite dairy commodity is purchased by firms and households. Our treatment of dairy purchases allows the application of our disaggregation routine without the need for data relating to New Zealand imports of disaggregated dairy commodities or Rest of World consumption of disaggregated dairy commodities.

Our specification nests two common specifications as special cases. When σ^T is equal to infinity there is a separate production function for each dairy commodity, each employing identical production functions. This specification is equivalent to that produced by SplitCom when there is perfect factor mobility and production cost shares are identical across sectors. When the elasticity of substitution between dairy commodities (across all sources of demand) is equal to zero, our dairy specification is identical to the case when there is only one dairy sector. This is because dairy commodities are demanded in fixed proportions when $\sigma^S = 0$, so, independent of σ^T, the dairy sector changes production of both dairy commodities by the same proportion as dairy prices vary. Similarly, neither producers nor consumers 'see' where the price change price change has occurred when there is a single dairy commodity, so they simply produce and consume, respectively, more of the aggregate dairy commodity.

The tariff on (aggregate) dairy products, t^d, is consistent with the following specification

$$t^d = \frac{\lambda}{\alpha} t^b + \frac{(1-\lambda)}{(1-\alpha)} t^s \tag{1}$$

where t^b and t^s are tariffs applying to butter and SMP respectively, λ is the butter tariff's contribution to the total dairy tariff ($0 \le \alpha \le 1$), and α is the share of butter production in total dairy production ($0 \le \alpha \le 1$). Equation (1), combined with the constraint that the value-weighted average tariff is equal to t^d, allows us to derive alternative values for t^b and t^s for different values of α and λ that are consistent with the dairy tariff recorded in the GTAP database.

In our numerical simulations, we assume that dairy production is split equally between butter and skim milk production (α = 0.5). In the base data, Rest of the World imposes a 9.1% tariff on (aggregate) dairy products. We shock the model by eliminating this tariff. The results for alternative values of σ^S , σ^T and λ are reported in Table 1. Initially, we set λ equal to 1 (so the pre-shock tariff on butter is 18.2% and that on SMP is zero). Column (1) displays results when $\sigma^S = 0$. As noted above, when $\sigma^S = 0$, the model behaves as if there is a single dairy sector, irrespective of values for α, λ, σ^T. The annual welfare gain to New Zealand from dairy liberalisation is equivalent to 1.6% of GDP. This is a substantial number, but not unexpected given the size of the tariff change, the significance of the dairy sector to New Zealand economy, and the nature of the shock, which gives New Zealand dairy products preferential treatment over Rest of World's imports from itself. There are also considerable increases in dairy output (104.2%) and exports (129.0%).

In column (2), consumers view the two dairy commodities as imperfect substitutes ($\sigma^S = 5$). Therefore, the tariff removal results in increased demand for New Zealand butter in Rest of the World, but New Zealand producers must produce the two dairy commodities in fixed proportions ($\sigma^T = 0$). The increase in SMP production must be absorbed by New Zealand and Rest of World markets. As a result, exports of both dairy commodities increase but the rise in butter exports (153.8%) is larger than the increase in SMP exports (101.6%). The increase in New Zealand welfare is also larger.

In our next simulation, we set σ^S and σ^T equal to 5. The results are reported in column (3). Allowing producers to (imperfectly) allocate dairy production across the two types of output results in a much larger production increase for butter (210.4%) than SMP (36.8%). Greater production flexibility also results in a larger increase in aggregate dairy production (127.6% versus 105.8% when $\sigma^T = 0$). Furthermore, the increase in dairy exports is larger than simulated previously, which is driven by a substantial increase in butter exports.

We set σ^T equal to infinity in column (4) to replicate a model built on a SplitCom disaggregation in which production cost shares are identical across commodities. As expected, production changes are much larger in this specification than for alternatives and the decrease in the relative price of SMP causes production of this commodity to decline. Following production changes, there is a large rise in butter exports (343.7%) and a decline in exports of SMP.

Comparing results across scenarios reveals that allowing producers and consumers to 'see' where the price change has taken place results in greater changes in the model. For example, increases in welfare, dairy production and dairy exports are, respectively, 48.7%, 38.0% and 38.3% larger in (4) than in (1). Changes in production and output of the disaggregated dairy commodities are even more sensitive to model specification.

So far we have assumed that the aggregate dairy tariff can be attributed to a tariff applying to a single dairy commodity (and the tariff on the other dairy commodity is zero). The extreme to this is when $t^d = t^b = t^s$ (which, as we set $\alpha = 0$, occurs when $\lambda = 0.5$). In this situation, tariff elimination does not change the relative price of the two dairy commodities so proportional changes in production and consumption will be the same across dairy commodities. As a result, irrespective of the value of σ^S and σ^T, the model will perform as if there is a single dairy sector.

An intermediate case occurs when $\lambda = 0.75$, which results in $t^b = 13.65\%$ and $t^s = 4.55\%$.[2] Simulations when $\lambda = 0.75$ and dairy tariffs are eliminated are displayed in Table 2. In column (1), as in our previous simulations, consumers and producers respond to the change in the aggregate dairy price (rather than changes in prices of the individual commodities), so the results are the same as the corresponding column in Table 1. In other simulations, the increase in the price of butter relative to the price of skim milk is smaller than when $\lambda = 1$. Consequently, changes in the variables of interest in columns (2), (3) and (4) are closer to those when there is only one dairy sector than in the corresponding columns in Table 1. For example, when $\lambda = 0.75$,

[2] As the model is symmetric, we do not consider situations where λ is less than 0.5.

increases in welfare, dairy production and dairy exports are, respectively, 12.5%, 9.8% and 10.3% larger in (4) than in (1).

In summary, our illustrative simulations show that the level of disaggregation can have a large influence on quantitative assessments of the impact of trade liberalisation. Discrepancies between aggregated and disaggregated results increase as the variation of tariff cuts across disaggregated commodities increases.[3] Providing tariff reductions differ across commodities discrepancies also increase (i) the larger the elasticity of substitution between disaggregated commodities, and (ii) the larger the elasticity parameter governing production transformation across disaggregated commodities (providing $\sigma^S > 0$). Moreover, our results reveal that it is not always appropriate to use SplitCom to disaggregate GTAP sectors when a finer level of sectoral aggregation is desired. Specifically, when two commodities are produced jointly, models built on a SplitCom version of the database produce unrealistically large production changes. An accurate representation of dairy production should model joint production for some dairy commodities (e.g., protein and fat) and account for transformation possibilities across production of other dairy commodities (e.g., cheese and whole milk powder).

3. Detailed dairy disaggregation

We analyse implications of disaggregation and joint production in a more comprehensive fashion by distinguishing nine dairy commodities. Using our modified production specification we consider the elimination of US dairy tariffs on imports from New Zealand. The US is the destination for 5.5% of New Zealand's dairy exports and is New Zealand's third largest overseas dairy market, behind Japan and Mexico.

New Zealand production shares and US imports shares for dairy commodities are displayed in Table 3. The products are an aggregation of commodities at the US tariff line (HS8).[4] Our aggregation distinguishes two protein products: SMP and other

[3] Although we eliminated tariffs that were unequal across commodities, reducing equal tariffs by different proportions produces results that are qualitatively similar to those observed above.

[4] Our disaggregation routine could in principle be applied at the tariff line. We choose to work with more aggregated data for ease of exposition and because reasons concerning confidentiality prevent us from displaying disaggregated tariff data.

protein. Other protein products include whey and milk protein concentrates, casein and albumins. We also identify two fat products – butter and anhydrous milkfat (AMF) – and three types of cheese – American-type, cheddar and cheese not specifically provided for (NSPF). Elsewhere, we also identify whole milk powder (WMP) and other products not elsewhere specified (NES), a catch-all for less important dairy products not neatly falling within our aggregation.

Production data, where possible, are sourced from the OECD. Where it is not possible to source production data which is comparable to our commodity level breakdowns we have used total export figures.[5] US tariff and New Zealand export data were sourced from the WTO Integrated Database (IBD). The US imposes specific tariffs on 19 of 37 dairy commodities (measured at the tariff line) sourced from New Zealand. We replace these tariffs with ad valorem equivalent (AVE) tariffs sourced from the US WTO 2001 IDB submission. The US also imposes a number of tariff rate quotas (TRQs) on dairy products. Key products for New Zealand attracting TRQs include butter, AMF, American-type cheese and cheddar cheese. We determine bilateral AVEs for TRQ products following the approach detailed by Bouët *et al.* (2006).

The data in Table 3 reveal that New Zealand dairy production is split roughly evenly across protein-fat and WMP production. Conversely, US dairy imports from New Zealand are dominated by protein products, which make up nearly 70% of US total dairy imports from New Zealand. According to our calculations, the average US tariff on New Zealand dairy products is 12.7% and there is considerable variation in US dairy tariffs across commodities. Other protein products, such as casein and milk powder, face very low tariffs. At the other extreme, the average tariff on fat-based products is 95% and the tariff on AMF is more than 111%.

We impose the production and imports shares in Table 3 in a disaggregated version of the GTAP database. We derive New Zealand consumption shares and Rest of World import shares of New Zealand dairy commodities residually so that production for each commodity equals total demand. We also scale tariffs so that the value-weighted

[5] We justify using export data to approximate production volumes as less five percent of New Zealand dairy production is consumed domestically.

average tariff on dairy products is equal to the US dairy tariff on New Zealand products recorded in the GTAP database (11.1%).

The production structure for dairy in New Zealand is outlined in Figure 2. In the first level of the production nest, dairy production is allocated across four products (protein and fat, WMP, cheese, and other dairy products NES) according the elasticity of transformation parameter σ^T_{MIL}. WMP and other dairy products are sold to firms and consumers. Protein and fat are divided into separate components according to the transformation parameter $\sigma^T_{P\_F}$. Further allocations of protein (SMP and other protein products) and fat (butter and AMF) are governed by elasticity parameters σ^T_{PTN} and σ^T_{FAT} respectively. Finally cheese output is divided into three varieties (American-style, cheddar and NSPF) with transformation possibilities dictated by σ^T_{CHS}. Regions other than New Zealand produce a single dairy commodity.

We consider five scenarios, which differ with respect to elasticity parameters used in our disaggregation procedure. Values of these parameters across scenarios are displayed in Table 4. In simulation (1), $\sigma^S = 0$ so the model behaves as if there is a single dairy sector (irrespective of the values of the CET parameters) and the results are equivalent to those generated by a standard aggregation of the GTAP database. The results, reported in Table 5, reveal a small increase in New Zealand welfare and an increase in dairy production of just under 2%.

Our second simulation allows consumers to substitute between dairy commodities, $\sigma^S = 3$, but producers must change output of all dairy commodities by equal proportions, $\sigma^T_{MIL} = \sigma^T_{P\_T} = \sigma^T_{PTN} = \sigma^T_{FAT} = \sigma^T_{CHS} = 0$. Allowing consumers greater flexibility results in a larger increase in US demand for New Zealand dairy products following our trade shock. The increase in New Zealand welfare is almost twice as large in simulation (2) as when a standard aggregation is used. The increase in New Zealand aggregate dairy output (4.7%) is also much larger in (2) than in (1).

In simulation (3), in addition to consumer substitutability, dairy producers are able to alter their product mix in response to price changes. The elasticities of transformation in simulation (3) were chosen in consultation with representatives from Fonterra, a New Zealand-based firm responsible for one-third of global dairy exports. In general, transformability increases as production becomes more refined. In the first level of the production nest, σ^T_{MIL} = 3. Further down the production nest, producers are unable to transform production between fat and protein, $\sigma^T_{P\_T}$ = 0, but transformation across protein, fat and cheese production is possible, $\sigma^T_{PRT} = \sigma^T_{FAT} = \sigma^T_{CHS} = 5$. The results in column (3) of Table 5 reveal that adding producer flexibility has little impact on the results at an aggregate level. That is, changes in welfare and aggregate dairy production are similar in columns (2) and (3). There are, however, large differences in results at the commodity level. When there is producer flexibility, the largest increase in production is for AMF, which has the highest pre-shock tariff.

Interestingly, production of both protein products expand (which attract an average pre-shock tariff of 0.1%) and production of butter (68.3%) decrease following our trade shock. These changes are a direct result of our chosen production structure. As protein and fat are produced jointly, the production of additional fat, due to the removal of high tariffs in fat-based products, requires production of additional protein, so there is increased output of SMP and other protein. Butter production, however, decrease as fat is diverted from this commodity into production of AMF production.

Elasticity parameters in simulation (4) are the same as those in (3) except that $\sigma^T_{P\_T}$ = 5. The numbers in Table 5 reveal that failing to account for joint production results in unrealistic changes in protein and fat production. Specifically, the proportional increase in protein production (4.0%) is much smaller than the corresponding increase in fat production (12.0%). The increase in fat output facilitates increased production of all fat-based products, including a large increase (24.7%) in AMF output.

In our final scenario, simulation (5), we set all elasticity of transformation parameters equal to infinity so that our model is equivalent to one built on a SplitCom disaggregation of the database (when all dairy commodities have identical production cost shares). Comparing results across columns reveals that SplitCom disaggregation exacerbates the problems identified in simulation (4). Specifically, in simulation (5), there is a much larger divergence in protein and fat output compared to (4), and the increase in AMF output is more than three-times as large than when joint production is accounted for.

4. Conclusions

This paper considered joint production and disaggregation in the dairy sector. We specified a disaggregation routine that nested a standard GTAP model and a model built on a SplitCom disaggregation as special cases. In an illustrative setting, we showed that disaggregation choice can have a large impact on simulation results, both at the sectoral and aggregate level. In a detailed application, we considered the removal of US tariffs on New Zealand dairy products. In our chosen application, disaggregation of dairy resulted in a welfare gain nearly twice as large as when dairy products were included in a single sector. The main driver of this result is the ability of consumers to substitute between different dairy commodities; that is, altering the production structure had little impact at an aggregate level. At a sectoral level, however, appropriately accounting for the practicalities of dairy production is important. Failure to account for joint production in the sector not only resulted in production changes that were incorrect by large orders of magnitude but also of the incorrect sign. Our preferred disaggregation and production specification differ from standard approaches.

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Figure 1: Illustrative dairy production structure

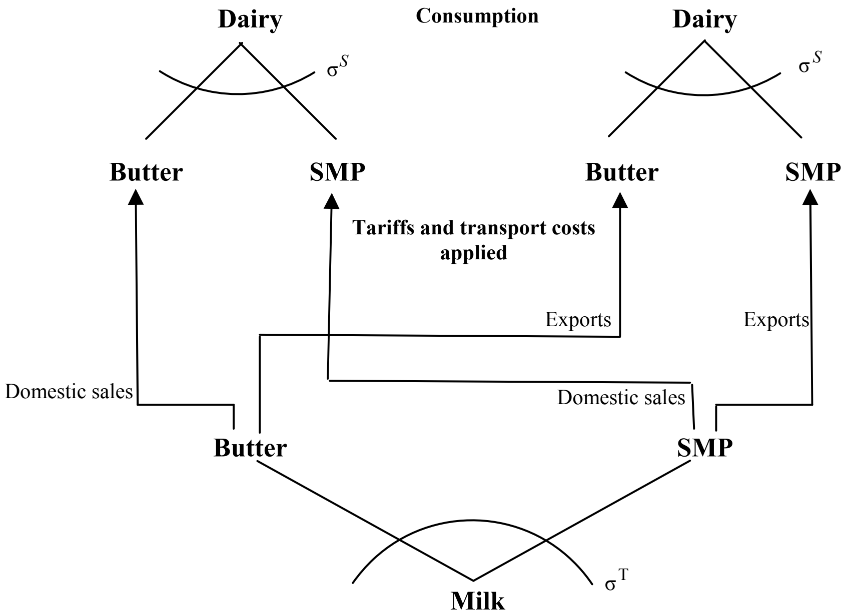

Table 1: Illustrative results for New Zealand, $\lambda = 1$ ($t^b = 0.182$ and $t^s = 0$)

	(1) $\sigma^S = 0$	(2) $\sigma^S = 5, \sigma^T = 0$	(3) $\sigma^S = \sigma^T = 5$	(4) $\sigma^S = 5, \sigma^T = \infty$
Equivalent variation, US$ m	729.0	807.6	957.2	1084.0
Equivalent variation, %	1.6	1.8	2.1	2.4
Dairy output, %	104.2	105.8	127.6	143.8
Butter	104.2	105.8	210.4	302.8
Skim milk powder	104.2	105.8	36.8	-14.7
Dairy exports, %	129.0	127.7	151.8	178.4
Butter	129.0	153.8	277.6	382.8
Skim milk powder	129.0	101.6	26.0	-26.0

Source: Simulation results as described in the text.

Table 2: Illustrative results for New Zealand, $\lambda = 0.75$ ($t^b = 0.1375$ and $t^s = 0.455$)

	(1) $\sigma^S = \sigma^T = 0$	(2) $\sigma^S = 5, \sigma^T = 0$	(3) $\sigma^S = \sigma^T = 5$	(4) $\sigma^S = 5, \sigma^T = \infty$
Equivalent variation, US$ m	729.0	749.1	785.9	819.8
Equivalent variation, %	1.6	1.7	1.7	1.8
Dairy output, %	104.2	104.6	110.0	114.4
Butter	104.2	104.6	151.6	195.6
Skim milk powder	104.2	104.6	66.7	33.2
Dairy exports, %	129.0	128.7	134.9	142.3
Butter	129.0	142.6	196.6	247.5
Skim milk powder	129.0	114.8	73.2	37.2

Source: Simulation results as described in the text.

Table 3: New Zealand dairy production shares and US imports shares and tariffs

	NZ production	US imports	US AVE, %
Dairy	**1.000**	**1.000**	**12.7**
Protein and fat	**0.497**	**0.766**	**8.9**
Protein	0.359	0.694	0.1
Skim milk powder	0.148	0.004	1.9
Other protein	0.211	0.691	0.1
Fat	0.139	0.071	95.0
Butter	0.088	0.027	68.3
AMF	0.051	0.044	111.5
Whole milk powder	**0.298**	**0.010**	**10.1**
Cheese	**0.178**	**0.210**	**27.1**
American-type	0.079	0.094	44.2
Cheddar	0.037	0.043	19.0
NSPF	0.062	0.073	10.0
Other products NES	**0.026**	**0.014**	**4.1**

Figure 2: Detailed dairy production structure

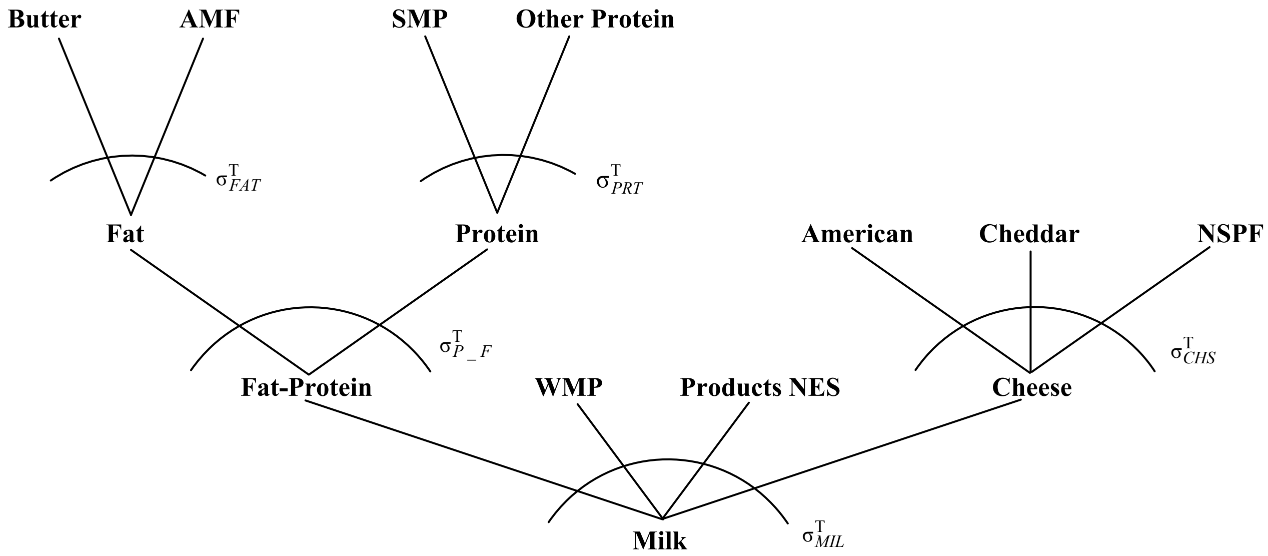

Table 4: Elasticities for alternative specifications

(1)	$\sigma^S = 0$
(2)	$\sigma^S = 3$, $\sigma^T_{MIL} = \sigma^T_{P\_T} = \sigma^T_{PTN} = \sigma^T_{FAT} = \sigma^T_{CHS} = 5$
(3)	$\sigma^S = 3$, $\sigma^T_{MIL} = 3$, $\sigma^T_{P\_T} = 0, \sigma^T_{PTN} = \sigma^T_{FAT} = \sigma^T_{CHS} = 5$
(4)	$\sigma^S = 3$, $\sigma^T_{MIL} = 3$, $\sigma^T_{P\_T} = \sigma^T_{PTN} = \sigma^T_{FAT} = \sigma^T_{CHS} = 5$
(5)	$\sigma^S = 3$, $\sigma^T_{MIL} = \sigma^T_{P\_T} = \sigma^T_{PTN} = \sigma^T_{FAT} = \sigma^T_{CHS} = \infty$

Table 5: Changes in New Zealand welfare and dairy production following the elimination of US bilateral tariffs

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
Equivalent variation, US$ m	15.6	29.0	29.5	29.9	30.4
Equivalent variation, %	0.035	0.064	0.065	0.066	0.067
Dairy products, %	1.9	4.7	4.9	5.0	5.2
Protein and fat	1.9	4.7	6.0	6.1	7.6
Protein	1.9	4.7	6.0	3.7	3.5
Skim milk powder	1.9	4.7	3.4	1.1	-0.8
Other protein	1.9	4.7	7.9	5.5	6.6
Fat	1.9	4.7	6.0	12.4	18.0
Butter	1.9	4.7	-0.7	5.3	6.0
AMF	1.9	4.7	17.5	24.7	39.0
Whole milk powder	1.9	4.7	2.1	2.1	-0.7
Cheese	1.9	4.7	6.9	7.0	9.1
American-type	1.9	4.7	10.1	10.2	14.4
Cheddar	1.9	4.7	5.2	5.2	6.3
NSPF	1.9	4.7	3.8	3.8	4.0
Other products NES	1.9	4.7	2.8	2.8	0.7

Source: Simulation results as described in the text.