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Dairy disaggregation and joint production in an economy-wide model[*]

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Abstract

We examine the impact of dairy disaggregation and joint production on trade liberalisation outcomes in an economy-wide model. Depending on parameterisation, our model includes either (a) a single dairy commodity, (b) several dairy commodities without joint production, or (c) several dairy commodities with joint production. In a numerical application, we consider the removal of US tariffs on dairy exports from New Zealand (the world's largest dairy exporter). We show that failing to account for joint production when dairy commodities are disaggregated leads to misleading results. Our preferred dairy production function differs from those used in other applied trade models.

Key words: Disaggregation, joint production, trade liberalisation

JEL codes: D58, F15

1. Introduction

Economy-wide (or computable general equilibrium, CGE) models are commonly used to evaluate alternative trade negotiation outcomes. Substantial data requirements necessitate the identification of relatively highly aggregated sectors in these models. This can cause severe aggregation issues, especially if exports from a region of interest are dominated by a sector that has not received the same degree of disaggregation as major export sectors in other regions.

Several recent projects have addressed aggregation issues. Horridge (2005) documents a utility, SplitCom, that facilitates disaggregation of sectors in a global, economy-wide model into two or more 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 tariff line analyses of US dairy protection using an economy-wide model that identifies 24 dairy commodities. We complement this literature by focusing on joint production in the dairy sector.

Milk protein is produced by extracting fat from raw milk. Consequently, protein-based and fat-based dairy products are produced jointly. Although joint dairy production has been considered in partial equilibrium studies (see, for example, Zhu *et al.* 1999), to our knowledge, this production feature has not been considered in economy-wide analyses. Consequently, production changes induced by trade liberalisation may be overestimated by conventional economy-wide models. We analyse the impact of joint production and dairy disaggregation using a production specification that nests (a) a single dairy commodity, (b) several dairy commodities without joint production, or (c) several dairy commodities with joint production as special cases. We do this using a set of constant elasticity of transformation (CET) functions to allocate a sector's output to alternative sub-sectors and by creating a constant elasticity of substitution (CES) dairy composite. The special cases outlined above are generated by choosing appropriate CET parameters and the elasticity of substitution between dairy commodities. Grant *et al.* (2007 & 2008) also use a CET function to allocate dairy production across alternative commodities. However, the authors do not consider joint production and assume that transformation possibilities across alternatives are equal. In contrast, we model joint production and allow transformation possibilities across commodities to differ. Our preferred production structure is guided by industry experts.

Our numerical simulations focus on New Zealand, the world's largest dairy exporter. Dairy distortions are relatively large, so production responses following trade liberalisation are likely to be sizeable. We first tease out important disaggregation features with and without joint production in an illustrative setting. We then consider the removal of US dairy tariffs on New Zealand products in a detailed analysis. Our framework can be applied to a subset of regions in a global, economy-wide model and requires a modest amount of additional data. Supplementary data include (a) output by sub-sector for the exporting region of interest, (b) exports from the region of interest to destinations of interest, and (c) trade distortions imposed by destinations of interest.

This paper has three further sections. Section 2 outlines our modelling framework. Section 3 examines the impact of disaggregation and joint production in an illustrative setting. Section 4 discusses the form of our detailed analysis and reports modelling results. Section 5 concludes.

2. Model structure

Our numerical simulations employ the 'GTAP6inGAMS' model. GTAP6inGAMS draws on version six of the Global Trade Analysis Project (GTAP) database (Dimaranan 2006) and is programmed using the General Algebraic Modelling System (GAMS). The GTAP database "combines detailed bilateral trade, transport and protection data characterising economic linkages among regions, together with individual country input-output data bases which account for inter-sectoral linkages within regions" (Hertel 2002, p.1-2). Version six of the database provides a representation of the global economy in 2001. Models like GTAP6inGAMS are widely used to investigate trade liberalisation outcomes.[1] The model is a static, perfectly competitive, multi-regional representation of the global economy that determines the production and allocation of goods. We outline salient features of the model below. Rutherford (2005) provides a detailed description.

Important empirical observations not replicated in standard trade models include intra-industry trade and failure of the law of one price for traded goods. Accordingly, imports in GTAP6inGAMS are differentiated by country of origin according to a CES function (i.e., the import demand specification is separable). Composite imports are also differentiated from domestic products using a CES function following Armington (1969). Elasticity parameters for our import specification are sourced from Hertel *et al.* (2007). In general, elasticities of substitution between imports from different

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[1] See, for example, Anderson and van der Mensbrugghe (2007), Francois and Wignaraja (2008), Grant *et al.* (2007), Rae and Strutt (2004), Robinson and Thierfelder (2002), and Scollay and Gilbert (2000).

sources are twice as large as elasticities governing substitution possibilities between composite imports and domestic goods.

Production technologies exhibit constant returns to scale and product and factor prices adjust to maintain zero profits. Output in each sector is governed by a Leontief nest of an intermediate input composite and a primary factor composite. The intermediate input composite is derived from a further Leontief aggregation of different products (which are themselves composites of domestic and imported varieties).

Expenditure in each region is allocated by a representative consumer. Expenditure shares across savings and government and private spending are constant. Savings is used as a proxy for future consumption, but the stock of capital is fixed. Private and government expenditure are Cobb-Douglas. As with intermediates, commodities entering final demand are composites of imported and domestic varieties.

Turning to closure, factor prices are endogenous, there is full employment, and factors are perfectly mobile across sectors (but immobile internationally). Fiscal balances are achieved by lump sum transfers from private households to governments. The capital account closure stipulates that savings and investment move together, so each region has a constant current account deficit.

3. Illustrative analysis

Our numerical simulations focus on New Zealand. This is an interesting country to investigate as New Zealand is the world’s largest dairy exporter, and dairy exports account for 16 per cent of this nation's total exports.[2] Version six of the GTAP database identifies 87 regions, a single dairy sector and 56 other sectors. Our illustrative analysis identifies two regions (New Zealand and Rest of World) and five sectors (dairy products, other agriculture, resource-based, 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 illustrative analysis is outlined in Figure 1. Dairy production is distributed across butter and SMP output 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 then reassembled using a CES function with elasticity parameter σ^S. The composite dairy commodity is purchased by firms and households, both domestically and abroad. Consequently, New Zealand butter and SMP does not compete directly with butter and SMP from Rest of World. Instead, agents choose between the New Zealand dairy composite and the aggregate dairy commodity produced by Rest of World. Following assignment of regional dairy expenditure, agents allocate expenditure on New Zealand dairy across butter and SMP. Our treatment of dairy purchases allows our framework to be applied without the need for data relating to New Zealand imports of disaggregated dairy commodities or Rest of World consumption of disaggregated dairy commodities.

[Figure 1 near here]

Our framework nests two common specifications as special cases. When $\sigma^T = \infty$, there is a separate production function for each dairy commodity, each employing identical

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[2] Uruguay's dairy exports contribute four per cent of this nation's total exports, which is the second-highest dairy export share across all regions included in the GTAP database.

technologies. This specification is equivalent to that produced by SplitCom when production cost shares are identical across sectors. When $\sigma^S = 0$ and butter and SMP expenditure shares are equal across regions, the model behaves as if there is a single 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 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 ($0 \leq \lambda \leq 1$), and α is the share of butter production in total dairy production ($0 \leq \alpha \leq 1$). 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 (aggregate) dairy tariff recorded in the GTAP database.

In our numerical simulations, we assume that dairy production and consumption in both regions is split equally between butter and SMP ($\alpha = 0.5$). In the base data, Rest of World imposes a 9.1 per cent tariff on (aggregate) dairy products. We shock the model by eliminating this tariff. Initially, we set $\lambda = 1$ (so the pre-shock tariff on butter is 18.2 per cent and that on SMP is zero). Results for alternative values of σ^S and σ^T are reported in Table 1. As expenditure shares on dairy commodities are equal across countries, the model behaves as if there is a single dairy sector when $\sigma^S = 0$, irrespective of values for λ and σ^T. We set $\sigma^S = 0$ in simulation (I.1a). We measure welfare changes using the Hicksian equivalent variation in income. The annual welfare gain to New Zealand from dairy liberalisation is equivalent to 1.6 per cent 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's 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 per cent) and exports (129.0 per cent).

[Table 1 near here]

We set $\sigma^S = 5$ and $\sigma^T = 0$ in simulation (I.2a), so consumers can respond to relative dairy prices but New Zealand producers must produce the two dairy commodities in fixed proportions. As a result, exports of both dairy commodities increase but the rise in butter exports (153.8 per cent) is larger than the increase in SMP exports (101.6 per cent). There is also a larger increase in New Zealand welfare in (I.2a) than in (I.1.a).

In simulation (I.3a), we set $\sigma^S = \sigma^T = 5$. Allowing producers to (imperfectly) allocate dairy production across the two commodities results in a much larger increase in butter production (210.4 per cent) than SMP output (36.8 per cent). There is also a larger increase in aggregate dairy production (127.6 per cent versus 105.8 per cent when $\sigma^T = 0$). The increase in dairy exports is also larger than simulated previously, which is driven by a substantial increase in butter exports (277.6 per cent).

We set $\sigma^T = \infty$ in simulation (I.4a), so there is a separate (identical) sector for each dairy commodity. The increase in butter exports in (I.4a) is substantial (343.7 per cent) and, unlike in other simulations, SMP exports decrease. Also, as SMP and butter production are no longer tied, the decrease in the relative price of SMP causes production of this commodity to decline. Comparing results for (I.2a) and (I.4a) indicates that assumptions regarding dairy production can have a large influence on modelling outcomes. When there is joint production, output of both dairy commodities increases by 105.8 per cent. When there is a separate sector for each dairy commodity, the increase in butter production is nearly three times as large as when there is joint production. Furthermore, changes in SMP output are of opposite sign in (I.2a) and (I.4a). Increases in welfare and aggregate dairy production are, respectively, about one-third and two-fifths larger in (I.2a) than (I.4a).

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 $\alpha = 0.5$, 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 identical across dairy commodities. As a result (and because dairy expenditure shares are equal across countries), the model mimics the case when there is a single dairy sector irrespective of the value of σ^S and σ^T.

An intermediate to the two cases discussed above occurs when $\lambda = 0.75$, which results in $t^b = 13.65$ per cent and $t^s = 4.55$ per cent. (As the model is symmetric, we do not consider situations where λ is less than 0.5.) Results when $\lambda = 0.75$ and dairy tariffs are eliminated are displayed in Table 2. In simulation (I.1b), 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 for (I.1.a). In other simulations, the increase in the price of butter relative to the price of SMP is smaller than when $\lambda = 1$. Consequently, changes in the variables of interest when $\lambda = 0.75$ are closer to those when there is a single dairy sector than when $\lambda = 0.5$. For example, when $\lambda = 0.75$, the increase in butter production in simulation (I.4) is only two-thirds as large as when $\lambda = 0.5$.

[Table 2 near here]

In summary, our illustrative simulations show that joint production and 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 (a) the larger the elasticity of substitution between disaggregated commodities, and (b) the greater the transformability of dairy production across disaggregated commodities (providing $\sigma^S > 0$). Moreover, our results reveal that it is not always appropriate to use SplitCom to disaggregate sectors when a finer level of sectoral aggregation is desired.

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[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.

Specifically, when two commodities are produced jointly, models built on a SplitCom version of the GTAP database overestimate production changes.

4. Detailed analyses

An accurate representation of dairy production should model joint production for some dairy commodities (e.g., protein and fat) and account for transformation possibilities for other dairy commodities (e.g., cheese and whole milk powder). We analyse the implications of disaggregation and joint production more comprehensively by distinguishing nine dairy commodities and considering the elimination of US dairy tariffs on imports from New Zealand.[4] The US is the destination for 5.5 per cent of New Zealand's dairy exports and is New Zealand's third largest overseas dairy market, behind Japan and Mexico. Examining New Zealand's dairy exports to the US is also interesting as the two nations have agreed to negotiate a free trade agreement through the Trans-Pacific Economic Partnership (Trans-Pac) initiative.

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).[5] Our aggregation distinguishes two protein products: SMP and other protein. We also identify two fat products (butter and anhydrous milk fat, AMF) and three types of cheese (American-type, cheddar and not specifically provided for, NSPF). Elsewhere, we 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.

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[4] In a related analysis, Alston *et al.* (2006) consider the liberalisation of dairy trade between Australia and the US.

[5] 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 confidentiality clauses prevent us from displaying disaggregated tariff data.

[Table 3 near here]

Production data, where possible, are sourced from the OECD's Commodity Balance Dataset. Where it is not possible to source production data comparable to our commodity level breakdown, we use total exports to calculate production shares. We are comfortable with this approximation as less than five percent of New Zealand's dairy production is consumed domestically. US tariff and New Zealand export data are sourced from the WTO Integrated Data Base (IDB). 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 attracting TRQs include butter, AMF, and American-type and cheddar cheese. We determine bilateral AVEs for TRQ products following Bouët *et al.* (2006). AVE tariffs for our nine dairy commodities are value-weighted averages of estimated tariff-line AVEs.

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 per cent of US total dairy imports from New Zealand. The average US tariff on New Zealand dairy products is 12.7 per cent and there is considerable variation in US dairy tariffs across commodities. Other protein products face very low tariffs. At the other extreme, the average tariff on fat-based products is 95 per cent and the tariff on AMF is more than 111 per cent.

We impose production and import shares in Table 3 on the GTAP database. We aggregate the database into three regions (New Zealand, the US and Rest of World) and five sectors (raw milk, dairy products, other agriculture, manufacturing and services). New Zealand dairy production is disaggregated into the nine dairy commodities identified above and there is a single dairy commodity in other regions. We choose New Zealand and Rest of World expenditure shares for dairy commodities so that production for each commodity equals total demand. We also scale US tariffs so that the value-weighted average tariff on aggregate dairy products is equal to the US tariff on New Zealand dairy in the GTAP database (11.1 per cent).

The structure of New Zealand dairy production is outlined in Figure 2. The production specification was designed in consultation with Fonterra, a New Zealand-based company responsible for one-third of global dairy exports. In the first level of the production nest, dairy production is allocated across protein-fat, WMP, cheese, and other dairy products according the elasticity of transformation parameter σ_{MIL}^{T}. WMP and other dairy products are sold to firms and consumers. Protein and fat are divided into separate components according to the transformation parameter $\sigma_{P\_F}^{T}$. Further allocations of protein (SMP and other protein products) and fat (butter and AMF) are governed by elasticity parameters σ_{PTN}^{T} and σ_{FAT}^{T} respectively. Cheese output is divided into three varieties (American-style, cheddar and NSPF) with transformation possibilities dictated by σ_{CHS}^{T}. Our production specification allows us to consider several alternative dairy production functions. On the demand side, as in our illustrative analysis, σ^{S} determines substitution possibilities between New Zealand dairy commodities, and a New Zealand dairy composite competes with dairy products from other countries.

[Figure 2 near here]

We consider five scenarios, which differ with respect to elasticity parameters. Values for these parameters across scenarios are displayed in Table 4. We set σ^S = 0 in simulation (D.1). The results, reported in Table 5, reveal a small increase in New Zealand welfare and an increase in dairy production of just under two per cent following our trade shock. Although σ^S = 0, specification (D.1) does not mimic a model with a single dairy sector as dairy expenditure shares on disaggregated dairy commodities differ across countries. However, results for (D.1) are broadly similar to when there is a single dairy commodity – New Zealand production of all dairy commodities increases by 2.8 per cent (not reported in Table 5) when there is a single dairy sector. Similar to our illustrative analysis, changing the values of transformation elasticities does not affect the results when σ^S = 0.

[Tables 4 & 5 near here]

Our second simulation, (D.2), allows consumers to substitute between dairy commodities, σ^S = 3, but producers must change output of all dairy commodities by equal proportions, $\sigma_{MIL}^T = \sigma_{P\_T}^T = \sigma_{PTN}^T = \sigma_{FAT}^T = \sigma_{CHS}^T = 0$. Allowing consumers greater flexibility results in a larger increase in US demand for New Zealand dairy products. The increase in New Zealand welfare is almost twice as large in simulation (D.2) compared to (D.1). The increase in New Zealand aggregate dairy output (4.7 per cent) is also much larger in (D.2) than in (D.1).

In simulation (D.3), in addition to consumer substitutability, dairy producers are able to alter their product mix in response to price changes. Elasticities of transformation in (D.3) were chosen with input from Fonterra. In general, transformability increases as production becomes more refined. In the first level of the production nest, σ_{MIL}^{T} = 3. Further down the nest, producers are unable to alter the relative production of fat and protein, $\sigma_{P\_F}^{T} = 0$, but transformation within protein, fat and cheese production is possible, $\sigma_{PRT}^{T} = \sigma_{FAT}^{T} = \sigma_{CHS}^{T} = 5$. The results 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 (D.2) and (D.3). However, there are large differences in results at the commodity level. In (D.3), the largest increase in production is for AMF, which has the highest pre-shock tariff. Interestingly, output of both protein products expand and butter production decreases, even though the pre-shock tariff on butter (68.3 percent) is significantly higher than the corresponding average protein tariff (0.1 percent). These changes are a direct result of our production structure. As $\sigma_{P\_F}^{T}$ = 0, additional fat production requires additional protein production, so there is increased output of SMP and other protein. However, butter production decreases as fat is channelled into AMF production.

Relative output changes for SMP and other protein are also interesting. The proportional increase in SMP production is less than that for other protein, even though the US tariff on SMP (1.9 per cent) is larger than that on other protein (0.1 per cent). This is because the New Zealand producer price for each commodity is a value-weighted average of prices across destinations. As the US SMP import share is much smaller than New Zealand's SMP production share and the opposite is true for other protein (see Table 3), the relative price of SMP falls. Similarly, there is a relative small increase in WMP production due to the small US import share for this commodity.

Elasticity parameters in simulation (D.4) are the same as those in (D.3) except that $\sigma^{T}_{P\_T} = 5$. The numbers in Table 5 reveal that failing to account for joint production results in unreasonable changes in protein and fat production. Specifically, protein production increases by 4.0 per cent and fat production by 12.0 per cent, which is unrealistic. The larger increase in fat output facilitates increased production of all fat-based products, including a large increase (24.7 per cent) in AMF output.

In simulation (D.5), we set all elasticity of transformation parameters equal to infinity and $\sigma^{S} = 3$. Consequently, there is a separate production sector for each commodity, as produced by the SplitCom utility (when all dairy commodities have identical production cost shares). Comparing results across simulations reveals that a SplitCom disaggregation exacerbates the problems identified in (D.4). Specifically, in (D.5), there is a much larger divergence in protein and fat output compared to (D.4), and the increase in AMF output is more than three-times as large as when there is joint production.

Overall, the results indicate that disaggregation and production structure both have a large influence on modelling results. A model that identifies a single dairy commodity underestimates production and welfare changes following trade liberalisation.

Conversely, when there are many dairy commodities produced independently, the model overestimates production and welfare changes. Our preferred production specification, (D.3), stipulates joint production for some dairy commodities but not for others.

5. Conclusions

This paper considered joint production and disaggregation in the dairy sector. We considered the impact of dairy liberalisation in an economy-wide setting using (a) a standard (single dairy sector) model, (b) a model built on a conventional disaggregation procedure (SplitCom), and (c) a model that considered both disaggregation and joint production for some or all commodities.

In an illustrative setting, we showed that the treatment of disaggregation and joint production can have a large impact on simulation results. In a detailed application, we considered the removal of US tariffs on New Zealand dairy products. In our chosen application, disaggregation of the dairy sector 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. At a sectoral level, appropriately accounting for the practicalities of dairy production is important. Failing to account for joint production not only resulted in production changes that were incorrect by large orders of magnitude but also of the incorrect sign. On the other hand, production changes are underestimated when all commodities are produced jointly. Our preferred dairy production structure includes joint production for some commodities, and differs from that used in other applied trade models (e.g., Grant *et al.* 2007 & Zhul *et al.* 1999).

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

	(I.1a) $\sigma^S = 0$	**(I.2a)** $\sigma^S = 5, \sigma^T = 0$	**(I.3a)** $\sigma^S = \sigma^T = 5$	**(I.4a)** $\sigma^S = 5, \sigma^T = \infty$
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 $t^s = 0.455$)

	(I.1b) $\sigma^S = \sigma^T = 0$	(I.2b) $\sigma^S = 5, \sigma^T = 0$	(I.3b) $\sigma^S = \sigma^T = 5$	(I.4b) $\sigma^S = 5, \sigma^T = \infty$
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**

Sources: (1) production data taken from the OECD's Commodity Balance Dataset; (2) import data sourced from the WTO IDB; and (3) Tariffs are value-weighted averages of AVE estimates of tariff-line trade distortions detailed in the WTO IDB.

Table 4: Elasticities for alternative specifications

(D.1) $\sigma^{S}=0$

(D.2) $\sigma^{S}=3$, $\sigma^{T}_{MIL}=\sigma^{T}_{P\_F}=\sigma^{T}_{PTN}=\sigma^{T}_{FAT}=\sigma^{T}_{CHS}=0$

(D.3) $\sigma^{S}=3$, $\sigma^{T}_{MIL}=3$, $\sigma^{T}_{P\_F}=0$, $\sigma^{T}_{PTN}=\sigma^{T}_{FAT}=\sigma^{T}_{CHS}=5$

(D.4) $\sigma^{S}=3$, $\sigma^{T}_{MIL}=3$, $\sigma^{T}_{P\_F}=\sigma^{T}_{PTN}=\sigma^{T}_{FAT}=\sigma^{T}_{CHS}=5$

(D.5) $\sigma^{S}=3$, $\sigma^{T}_{MIL}=\sigma^{T}_{P\_F}=\sigma^{T}_{PTN}=\sigma^{T}_{FAT}=\sigma^{T}_{CHS}=\infty$

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

	(D.1)	**(D.2)**	**(D.3)**	**(D.4)**	**(D.5)**
Equivalent variation, US$ m	15.7	29.1	29.5	29.6	30.5
Equivalent variation, %	0.035	0.064	0.066	0.066	0.068
Dairy products, %	1.9	4.7	4.9	5.0	5.2
Protein and fat	1.9	4.7	6.1	6.2	7.6
Protein	1.9	4.7	6.1	3.7	3.3
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	6.1	12.5	18.0
Butter	1.9	4.7	-0.7	5.3	6.0
AMF	1.9	4.7	17.7	24.9	39.3
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	6.2
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.

Figure 1: Illustrative dairy production structure and consumption

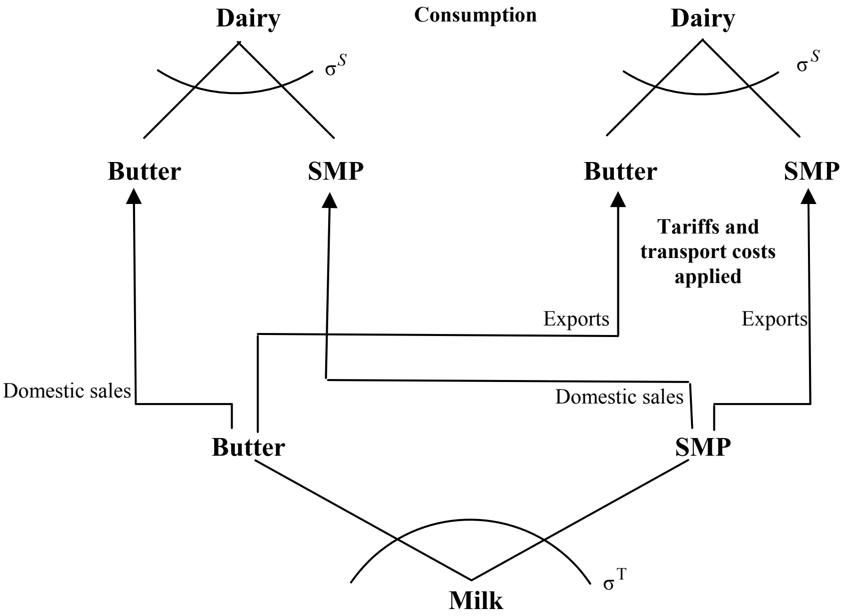

Figure 2: Detailed dairy production structure