Effects of domestic support on dairy trade

Decomposing the effects of different types of direct payments

SENSE PARTNERS

DATA LOGIC ACTION

Contents

1. Summary

1.1. Purpose

This report describes the effects of direct producer support payments on global dairy trade and producer prices, broken down by product type and type of payment.

We classify payment types using the WTO amber, blue and green box classifications, and test whether WTO green box spending is 'minimally trade distorting' as it is supposed to be.

We test the effects of direct producer support payments via four reform scenarios in which OECD countries:

1. eliminate direct producer support payments in the amber and blue boxes

2. eliminate direct producer support payments in the green box

3. eliminate all direct producer support payments

4. shift all direct producer support payments to green box programmes, maintaining total domestic support spending.

For simplicity, we use the term subsidies as a short-hand to refer to these direct producer support payments. However, our analysis excludes:

- market price supports, such as guaranteed minimum prices

- domestic food aid and public stockholding for food security purposes

- spending on general services such as research and education.

Our analytical focus is on the international effects of subsidies, though to explain results to our local audience we also discuss effects on New Zealand.

1.2. Key results

1.2.1. Green box subsidies are not minimally distorting

We find evidence that, on average, direct payments in the green box are trade distorting. Whether one would consider the size of the distortions "not more than minimal" depends on the product.

- The effects of green box subsidies on skim-milk powder (SMP) trade are substantial, around one half the size of the impact of the more distorting amber and blue box subsidies.

- The impact of green box subsidies on the butter market is larger than the impact of blue box and amber box subsidies.

- In contrast, green box spending has small effects on the cheese and whole-milk powder (WMP) markets.

Variation in effects across products is partly a compositional effect; how intensely the different types of subsidies are used by countries, whether countries are large consumers or producers of those products, and interactions between subsidies and other policies that distort trade.

1.2.2. As expected, the amber and blue boxes are most distorting

Amber and blue box spending has much larger effects on trade than green box spending. So much so that that there only small differences in the effects of eliminating amber and blue box spending and shifting amber and blue box spending into the green box.

This result affirms the notion that green box subsidies are much less distorting than other subsidies, even if not necessarily minimally trade distorting.

1.2.3. Benefits from subsidy reform are impeded by other trade costs

Like many modelling analyses before this one, we find that subsidy reform is beneficial by improving the efficiency of production and expanding opportunities for gains from trade and consequent consumer welfare benefits.

Benefits of subsidy reform in the cheese market are impeded, however, by other trade barriers. There are sufficiently high barriers to trade to prevent the global cheese market adjusting as other markets do.

In the cheese market when subsidies are removed production declines in several major cheese producing countries. While this would be expected to lead to price increases that draw increased supply from other countries, rebalancing is impeded by high trade costs. EU tariffs and quotas are notable examples of these trade costs and they have significant effect on the rebalancing of trade due to the EU being home to around half of global cheese demand.

We use the term trade costs to mean anything that adds costs to trade, whether e.g.

- transport costs

- spoilage or losses

- tariffs

- subsidies

- marketing costs

- language barriers

- variations in product standards

- testing and conformance requirements

- licensing

- certification.

1.2.4. New Zealand gains from subsidy removal

Elimination of all OECD country subsidies boosts dairy sector incomes, for the products we have analysed, by 40 million annually (2019 US dollars), mainly via increased producer prices (+1.8% in the SMP market). This amounts to a 0.5% increase in dairy sector income. This finding is within the range of results found in other studies; perhaps a little at the low end.

This study differs from other studies by analysing trade in groups of dairy products, rather than aggregate dairy product trade, and by direct empirical estimation of the effects of subsidies on trade.

The direct effects of subsidies on trade are significant, but the net effects of reform on New Zealand producers is more muted because:

(i)   New Zealand is a long way away from many OECD markets that are intensive in their use of subsidies, and for whom subsidy removal has the largest impacts on domestic production.

(ii)   New Zealand faces high market access barriers (tariffs, TRQs, non-tariff barriers) that do not disappear when subsidies are removed. So even though subsidy removal leads to additional consumer demand in OECD markets, the opportunities for New Zealand exporters remain limited.

(iii)   New Zealand's existing dairy trade relationships tend to be with markets where trade costs are much lower (e.g. China, Australia) and the vast majority of New Zealand trade is with countries that are outside the OECD and are much less affected (directly) in these OECD subsidy reform. That is, subsidy removal in OECD countries is not sufficiently material in reducing trade costs to drive New Zealand exporters to divert much trade away from these existing relationships.

These observations are not unique to New Zealand. Policy effects are typically not large enough to alter the relative ranking of exporters in terms of overall height of trade costs (barriers) affecting trade.

An illustration of these observations regarding scale of trade costs is shown in Figure 1 and Figure 2 below using trade costs for exporters to the US as an example. Figure 1 shows policy-related costs as a share of total trade costs and Figure 2 shows the size of trade costs after removing the effects of subsidies.

1.3. Important caveats

1.3.1. Average international effects

Our analysis is not an assessment of individual countries' domestic support programmes. For example, we find that green box spending distorts trade, on average, but that does not mean all countries' green box programmes are trade distorting or that every green box programme
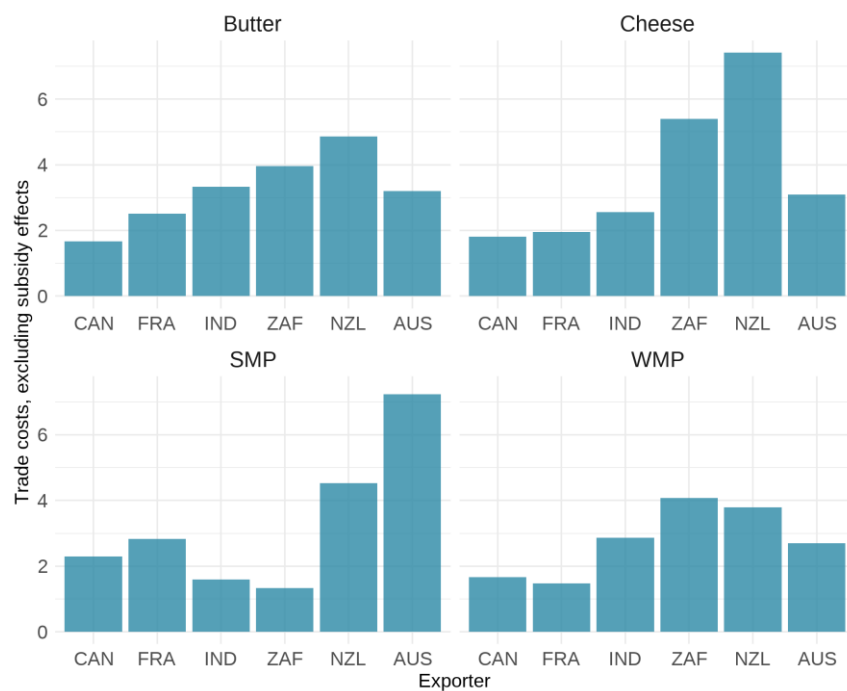
is trade distorting. Further detailed analysis of specific policies and programmes would be needed to infer the degree of distortion from individual countries' policies.

FIGURE 1: POLICY EFFECTS – SHARES OF TRADE COSTS

FIGURE 2: TRADE COSTS WITH THE US, AFTER REMOVING SUBSIDY EFFECTS

The analysis also focusses on the effects of policies in OECD countries. This does limit the implications of the analysis for global trade policy. However, we are mindful that policies in developing countries often have broader objectives that add further – context specific – complexity to analysing the effects of domestic support and recommend country-specific analysis.

That said, these caveats do not undermine the finding that green box spending should not be presumed to be minimally trade distorting.

1.3.2. Scope of analysis excludes market price support

Our measure of domestic support is based on OECD data on spending on producer support and direct payments to producers. It excludes non-tariff market price support programmes.

Our approach here is the same as that taken by other international trade analyses, where market price support is excluded from analysis because it measures both tariff effects and other price intervention effects (Anderson et al, 2021; Boysen-Urban et al, 2020). To the best of our knowledge, there are no international trade data sets or modelling research that decomposes market price support into tariff effects and effects of other policies.

The absence of non-tariff market price support from our analysis means that our measure of subsidies understates the full effect of domestic support on trade.[1]

The effects of market price support are potentially very distortionary but are typically market- and programme-specific and frequently vigorously debated.[2] That being so more detailed market-specific analysis is left for future research.

This study also excludes general services support spending which covers the likes of infrastructure spending, research, establishment of sector institutions and education. This spending does not directly alter producer receipts or costs or consumption expenditure.

1.3.3. This is a sector analysis, overlooking wider effects

We have not analysed wider economic effects such as benefits from reallocation of resources outside of dairy production or repurposing of government revenue to alternative uses.

Moreover, subsidy reform is a question affecting a wide range of food and fibre products beyond dairy. So this dairy-specific analysis is only part of the picture. For example, less subsidised and more productive producers in other primary sectors may benefit from reduced domestic support payments if it means a reduction in input prices through lower competition for resources.

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[1] The modelling we use does include measures of trade costs that reflect all trade costs so that the effects of market price support is implicitly captured in our analysis, but we cannot identify the size of that effect or simulate the effects of reforming market price support.
[2] There is, for example, a lot of debate at the WTO over whether public stockholdings of food for food security purposes are, in some countries, being administered in a trade distortive way i.e. buying stocks at a premium and selling them at a discount.

2. Motivation

Agricultural producer support payments have plateaued…

Total direct producer support payments, across all agriculture, have plateaued in the past 15 years, as a share of farm income. And countries have shifted support into programmes that, on the face of it, should have limited distortionary effects on world trade – such as the green box.

…but plenty of subsidies remain in the global dairy market

These developments are positive but should these developments be the end of the road? To what extent do subsidies continue to distort trade and impose global welfare costs?

The dairy sector is often a target for producer support, but the extent to which domestic support payments continue to have important distortionary impacts on trade is unclear. This is partly because it is hard to measure the size of producer support payments in the dairy sector when payments are made via the green box, because these payments are not flagged as being dairy sector support payments.

Furthermore, there appears to have been an increase in spending targeted at wider policy objectives (such as environmental outcomes) and that sort of spending typically falls inside the green box, given its purpose, but the impacts of that spending may not align with the intent of the green box in terms of being minimally trade distortive, due to how the support is delivered.

Robustly analysing the impact of dairy sector subsidy reform requires putting simple assertions to one side…

Most analyses rely on strong assumptions about the effects of subsidies on production e.g. focusing on the extent to which subsidy payments are conditional on production and therefore stimulate (inefficient) production and reduce prices and incomes of producers that are not subsidised. Thus the effects of subsidies less well-connected (coupled) to production are not scrutinised as much.

Focusing on payments that are explicitly linked to production is a reasonable starting point but misses a range of potential effects of subsidies, particularly dynamic effects on productivity and human motivation and behaviour.

For example, there are numerous studies that point to reduced efficiency of milk production due to subsidies which, other things being equal, raises costs and prices (Minviel and Latruffe, 2017; Nilson and Wixe, 2022). If that is so, then reducing subsidies may well stimulate improved efficiency, lower costs, raise output and lower prices. The effect on trade and the incomes of unsubsidised producers is ambiguous.

Subsidies that are not linked to production (decoupled) are also likely to have wealth effects. That is, security of income streams can keep inefficient producers or farms in production or cause inefficiently high degrees of risk-taking. Plus additional sources of income may improve

farmers access to credit. So even green box subsidies can contain incentive effects that distort production and trade.

The effect of green box spending on trade is an active area of research internationally and there is no consensus on the direction or size of these effects although one recent study of EU domestic support did find evidence that green box subsidies are significantly trade distorting (Boysen-Urban et al, 2020).

Also, many ostensibly decoupled subsidies are cost-increasing, such as payments conditional on meeting environmental objectives. Those cost-increasing effects will tend to increase output prices and potentially moderate wealth effects associated with subsidy payments.

…and letting the data tell the story

So the overall effects of subsidy programmes is ambiguous and the net effects of different types of subsidies is an empirical matter. That is, we need to be careful not to impose on the model too many assumptions about how global dairy trade works and its interactions with multiple policy measures and other factors that drive trade (e.g. distance).

Thus the value added of this analysis is to rely upon empirical analysis to measure the effects of different subsidy programmes.

Existing studies are unclear on what to expect from subsidy reform

Existing studies of the effects of subsidies on trade do not provide consistent or detailed results of the effects on the dairy sector. By way of example, Table 1 summarises the findings of relatively recent studies that are somewhat comparable to the sorts of results presented in this study. We have not found any studies that are more comparable.[3]

Each of the studies in Table 1 are produced using similar models adapted for the purpose of studying the effects of subsidy reform.[4]

The first study in the table shows large effects on European countries but negligible effects on Australia and New Zealand from substantial changes to the EU common agricultural policy (CAP). The study also shows small but positive increases in world output prices for agricultural products. The study does not distinguish impacts on dairy trade but predicts a 0.4% reduction in dairy output and a dairy product market price increase of 0.4% in the EU-28. The study also finds small welfare losses in countries that are net importers of food, due to increases in food prices.

The second study of Anderson et al (2021) simulates elimination of all agricultural subsidies in the world and finds substantial increases in world dairy production and prices, though higher

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[3] Other studies do exist, but they are old or their data is old and reflect the subsidy and trade landscape as it was in the 1990s. These other studies are also often based on analytically simplified models that do not account for relative prices and trade costs across the world e.g. Banga (2016).
[4] All of these studies are based on versions of the GTAP computable general equilibrium model, with augmented databases.

prices lead to reduced exports. The study does not provide comprehensive information on the geographic breakdown of these effects but does detail impacts by broad region and high-level sector aggregates. Results for the food processing in Oceania, for example, show a 3.4% increase in exports and a 1.40% increase in production. However, reallocation of resources within the economy and cost increases associated with expanding production mean that real GDP effects are small (0.02%).

The third and most recent study suggests that subsidy elimination would reduce dairy prices and increase exports - reversing the finding of the Anderson et al (2021). This effect is explained as the result of more efficient producers expanding production and reducing costs of global production. Regional impacts in terms of GDP are small.

The third study usefully provides a comparison between domestic support reform and tariff elimination. The results suggest that tariffs have larger effects on world trade than subsidies.

These findings will naturally differ from ours in so far as they are more aggregated, based on reform scenarios that are both smaller and larger than the reforms considered here (where we limit reform to OECD countries) and use general equilibrium models capable of calculating economy-wide effects.

Nonetheless these findings are of some use in placing ranges around the sorts of effects we might expect in our results e.g. price effects ranging from -3.7% to 5.2%.

TABLE 1: EXAMPLES OF RESULTS FROM STUDIES OF SUBSIDY REFORM

Source	Policy scenario/effects	Measure	Impact
Boulanger and Philippidis (2015)	EU CAP spending halved	World agricultural output prices	0.60%
		Australia & NZ real GDP	0.01%
Anderson et al (2021)	Global agriculture subsidy removal	World dairy production	3.50%
		World dairy exports	-3.90%
		World dairy export prices (average)	5.20%
		Oceania real GDP	0.02%
		Oceania processed food production	1.40%
		Oceania processed food exports	3.40%
Holtman et al (2022)	Global subsidy removal	World dairy production	1.90%
		World dairy exports	9.80%
		World dairy prices	-3.70%
		Australia real GDP	0.004%
	Global tariff removal	World dairy production	-0.10%
		World dairy exports	14.6%
		World dairy prices	-0.45%
		Australia real GDP	0.013%

3. Method

3.1. Model and data

Our analysis is based on a global dairy distortions model (GDDM) that has been recently developed in New Zealand for the purposes of analysing effects of policies on global dairy trade.

The model is a structural gravity model (see technical appendix) using a bespoke database of international dairy product production, trade and expenditure.[5, 6]

The products included in this analysis are:

- butter

- cheese

- skim-milk powder (SMP)

- whole-milk powder (WMP).

The model is calibrated[7] to trade data over the period 2013 to 2019, although policies included in the model span the ten years from 2010 to 2019, via lagged effects of policies on trade. These lagged policy effects are included to allow for protracted adjustment to policies through e.g. investment responses.

The full database includes 111 countries, however our data on domestic support is limited to 57 countries, so our analysis includes a 'rest of world' aggregate without data on domestic support. This 'rest of world aggregate is a large share of New Zealand exports, ranging from 23% of cheese exports to 49% of WMP exports in 2019.

Incomplete time series data on production and consumption of some products further limits the number of countries included in the model and means the number of countries and amount of world trade included in the models varies by product (see Table 2).

[5] The model includes estimates of domestic trade, to permit identification of non-discriminatory policies on dairy trade.
[6] The database is created using publicly available data sources: UN FAO and Comtrade data on trade, production, and non-tariff measures; World Bank data on tariffs; OECD, WTO, EU data on domestic support; CEPII data on institutional and geographic measures.
[7] The model uses so-called estibration, which combines econometric estimation with calibration (Anderson et al, 2018)

TABLE 2: COUNTRY AND TRADE COVERAGE BY PRODUCT

Products	Countries	% of world trade[8]
Butter	50	95%
Cheese	50	96%
SMP	44	67%
WMP	45	61%

3.2. Domestic support measures

Data on direct producer support payments has been taken from the OECD producer support estimates database. Spending has been assigned to WTO green, amber and blue boxes based on a line-by-line assessment of policies (see Appendix).[9]

The data has been arranged by farm type eligibility as shown in Table 3. These nominal expenditure data have been converted to rates by dividing through by gross farm output within each applicable sector, shown in Table 4.

For the model analysis the data for non-dairy sector support has been aggregated to a single measure for support available to livestock producers, including support available to any producer who may or may not be a dairy or livestock producer – converted into a domestic support rate per dollar of gross output of eligible sectors.

3.3. Policies included in the model

The range of policy effects included in the model is determined with a statistical model that seeks to optimise predictive accuracy and drops explanatory variables where that improves predictive accuracy.[10]

This approach is used because the range of candidate policy variables is large and often those variables are highly correlated with the production, expenditure and bilateral trade effects being estimated in the model. Those features of the data cause variables to be excluded from conventional regressions, even if they are important in terms of prediction, or very high variance (imprecision) in estimates of policy effects.

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[8] Share of world trade in 2019.
[9] For a similar approach see Josling and Mittenzwei (2013).
[10] The model is an elastic-net version of a conventional structural gravity model with origin-year, destination-year and pair fixed effects. The regression model includes penalties on fixed effects that are one-tenth the size of penalties on policy variables and an alpha hyper-parameter of 0.5.

TABLE 3: DOLLARS OF DOMESTIC SUPPORT BY WTO BOX AND TARGET SECTOR OVER TIME
US dollar millions, based on OECD producer support estimates

Box	Supplied to	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Amber	Dairying	3,407	2,473	2,612	2,917	3,536	2,074	1,886	1,920	1,972	1,893	2,033
	Ruminants	6,233	6,353	7,755	8,190	6,788	5,587	2,620	2,496	2,161	2,110	1,800
	Livestock	3,570	3,594	6,668	6,857	8,365	7,374	6,091	5,820	6,350	6,719	6,190
	Any producer	46,098	43,551	47,983	49,182	48,779	49,141	51,342	52,490	59,928	60,135	58,327
Blue	Dairying	241	281	311	330	333	315	1,175	1,208	1,253	1,327	1,270
	Ruminants	98	91	91	85	88	98	2,501	2,629	2,760	2,800	2,622
	Livestock	338	361	399	406	412	397	323	282	265	311	275
Green	Dairying	0	65	72	72	59	56	49	54	54	54	420
	Ruminants	60	56	52	49	55	54	62	61	63	63	57
	Livestock	1,149	1,838	1,092	887	812	673	903	786	815	793	816
	Any producer	91,097	91,918	98,702	95,550	98,816	102,130	86,375	87,870	87,623	93,952	102,647
Total	Total	152,290	150,582	165,738	164,525	168,044	167,899	153,326	155,616	163,244	170,156	176,456

TABLE 4: DOMESTIC SUPPORT RATES BY WTO BOX AND TARGET SECTOR OVER TIME
Payments divdied by gross output (e.g. 0.5 = 50%)

Box	Supplied to	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Amber	Dairying	0.17	0.08	0.10	0.09	0.14	0.10	0.09	0.09	0.10	0.09	0.09
	Ruminants	0.07	0.09	0.10	0.07	0.06	0.04	0.05	0.05	0.06	0.06	0.08
	Livestock	0.06	0.06	0.05	0.05	0.05	0.04	0.02	0.02	0.02	0.03	0.02
	Any producer	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.06	0.06	0.07	0.07
Blue	Dairying	0.36	0.41	0.47	0.48	0.49	0.46	0.09	0.08	0.08	0.10	0.09
	Ruminants	0.09	0.08	0.08	0.08	0.08	0.09	0.03	0.03	0.04	0.04	0.03
	Livestock	0.22	0.23	0.26	0.27	0.26	0.26	0.21	0.18	0.17	0.19	0.17
Green	Dairying	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
	Ruminants	0.10	0.11	0.15	0.14	0.14	0.17	0.11	0.13	0.16	0.15	0.14
	Livestock	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.00
	Any producer	0.14	0.15	0.16	0.16	0.16	0.15	0.12	0.12	0.12	0.13	0.11
Total	Total	0.11	0.12	0.13	0.12	0.12	0.11	0.09	0.09	0.09	0.10	0.09

This approach also has the advantage of providing a systematic and replicable approach to selection of variables to include – as opposed to inclusion of variables based solely on prior beliefs.[11] It is thus more objective than most alternative model selection methods.

Efforts to improve objectivity are important to this analysis because we are seeking to determine if e.g. green box subsidies are trade distorting when the conventional view is that they are not. That is, simply including green box policies in our model could be taken to be pre-ordaining an effect on trade. Our model selection method means green box subsidies are included in the model if they have important predictive value as determined by objective statistical criteria.

Prior beliefs do come into play, however, in specifying the list of candidate policy variables to be modelled. The following policy variables were included for selection:

- tariffs, with lagged effects of up to 3 years

- free trade agreements, with a contemporaneous effect and an effect lagged 3 years

- EU milk quota effects[12], with directional effects on EU member state exports and imports

- domestic support measures, by WTO box, by sector of targeting (whether dairy-specific or more generally available), with a contemporaneous effect and up to three lags and separate (directional) effects on imports and exports (see Table 5)

- interaction effects between EU domestic support and intra-EU trade.

The tariff data includes estimates of the ad valorem equivalents of specific tariffs (dollars per quantity) and tariff rate quotas. The estimates of ad valorem equivalents of tariff rate quotas are imperfect as measures of economic consequences of tariff rate quotas because e.g. they do not capture quota rents. However the modelling methods we use, with fixed effects, will ensure that effects of quotas are captured in estimated trade costs alongside other causes of trade costs that are not directly measured in our data on policies.

EU interaction effects help to eliminate any EU-specific effects from our estimates of average international effects of policies. The EU is a large part of dairy trade and of our data set. We thus expect that the effects of EU policies could have a material impact on our estimates of average policy effects internationally and may well pick up effects that are specific to the common market, the euro area (to the extent applicable) or the Common Agricultural Policy.

The full range of candidate domestic support variables is shown in Table 5, including the EU interaction terms. Each of the cell in the table reflects a variable included in the long list of variables. Each of the cells with a value in it shows the effects of that variable on trade flows in terms of percentage change in trade given a percentage change in domestic support.

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[11] Or methods involving selection on statistical significance, which is, in general, considered poor practice but is nonetheless often done.
[12] Capturing the effect of removal of the EU milk quotas in 2015.

TABLE 5: DOMESTIC SUPPORT VARIABLES – CANDIDATES AND SELECTION

Estimated effects (% impact on trade, for a 1% change in subsidy rate). Empty cells denote variables excluded during model selection.

Sector	Box	Region	Lag	Exports				Imports			
				BTR	CHS	SMP	WMP	BTR	CHS	SMP	WMP
Dairy	Amber	All	0	0.0							
			1	-0.3		-0.6	-0.1		-0.1		
			2		-0.3		0.0		-0.2		
			3	-0.2	-0.5		-0.1		-0.2		
		EU	0	-0.7	-0.4						
			1	-0.5	-0.6						
			2		-1.0						
			3		-1.1						
	Blue	EU	0	12.7	18.9	0.4					
			1		1.6	4.0					
			2	7.5		0.2					
			3		1.8	0.2					
Livestock	Amber	All	0	-0.6		-0.5	-2.5	-2.7	0.0	-1.9	-2.3
			1	-1.8		-2.1	-1.9	-1.0		-2.5	-1.2
			2	-1.5		-2.8	-2.0	-0.7		-2.1	-0.4
			3	-1.0		-2.1	-2.6	-1.6		-3.0	-2.4
	Blue	EU	0		10.1						
			1								
			2								
			3		0.8						
	Green	All	0	-2.1		-0.4	-0.2	-0.9			-0.8
			1	-1.0		-0.1		-0.2		0.0	-0.3
			2			-1.3				-1.7	0.0
			3		0.5	-0.9				-0.4	-0.6
		EU	0			0.1					
			1	0.0		0.5					
			2	0.2		1.3					
			3	1.6	0.4						

The EU interaction effects are specified only as export effects. The effects are symmetric import-export effects as they only ever involve both an EU export and EU import.

4. Direct effects of subsidies on trade

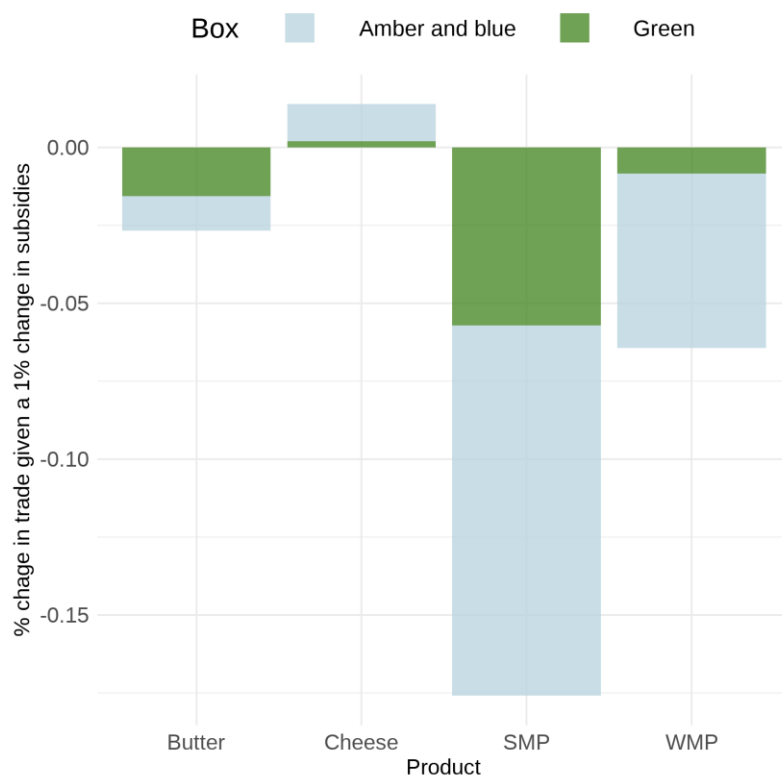## 4.1. Green box spending <u>does</u> distort trade

Our estimates of the direct effects of subsidies on trade suggest that green box spending is not minimally trade distortive, although the effects appear to vary by product.

The largest effects of subsidies are on trade in SMP and WMP, with -18% and -6% effects respectively (see Figure 3).

Amber and blue box subsidies dominate these effects but green box subsidies are 32% of the overall effect of subsidies on SMP trade and 13% of the effect on WMP trade.

In the case of trade in butter the green box makes up 58% of the 2.7% trade reducing effects of subsidies.

FIGURE 3: DIRECT EFFECT OF SUBSIDIES, ON TRADE BY BOX
Average percent change in trade given a percent change in subsidies.[13]

The size of these average effects do not translate directly into impacts on trade of coordinated subsidy reform, across several countries. With coordinated subsidy reform, effects on trade

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[13] Trade weighted averages.

will depend on the changes in the relative size of trade costs and those changes are a function of:

- the size of the change in subsidies in the reforming countries

- the size of subsidies in any non-reforming countries

- the direct effects on bilateral trade – the effects shown in Figure 3

- the change in each country's global average import and export costs, often referred to as multilateral trade resistance.

These direct effects are also partial measures of effect in the sense that they do not account for flow-on effects such as increases or decreases in production.

The direct effects include effects from substitution across products. In other words, subsidies that reduce SMP trade may have lifted cheese trade or reduced the effects of subsidies on butter trade.

The size of the effects by product also reflects correlations between countries' specialisations in dairy production and trade and their use of subsidies. Figure 4 demonstrates this, showing that SMP tends to be exported by countries with higher-than-average subsidies and this relationship has increased over time.

The data in Figure 4 is an index showing whether product trade shares, by country, match subsidy shares over time. A value above one shows most exports of the product come from countries with below average domestic support and a value below one means the majority of trade is from countries with below average domestic support spending.

The data in Figure 4 also shows that there has been a shift over time in the trade of subsidising countries, away from WMP towards SMP, for example, and there was a jump in trade in SMP by subsidising countries in 2017 to 2019 – probably a reflection of EU intervention in the SMP market between 2016 and 2019.

4.2. Subsidies are but one component of trade costs

The direct effects of subsidies on trade may appear large but need to be considered in the context of the overall size of costs that impede trade. In that context, subsidies are not generally a large part of trade costs, although that observation varies by trading partners.

Table 6 provides an illustration of the relative size of subsidies by way of an example of the composition of trade costs impeding imports into the United States.[14] Notably the majority of

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[14] These trade costs are illustrative. They have been constructed assuming a constant trade elasticity of 9. In practice, our model estimates trade costs inclusive of trade cost and substitution elasticities and the two are not separately identified. However, the relative sizes of the cost components are a reasonable reflection of relative importance in impeding trade.
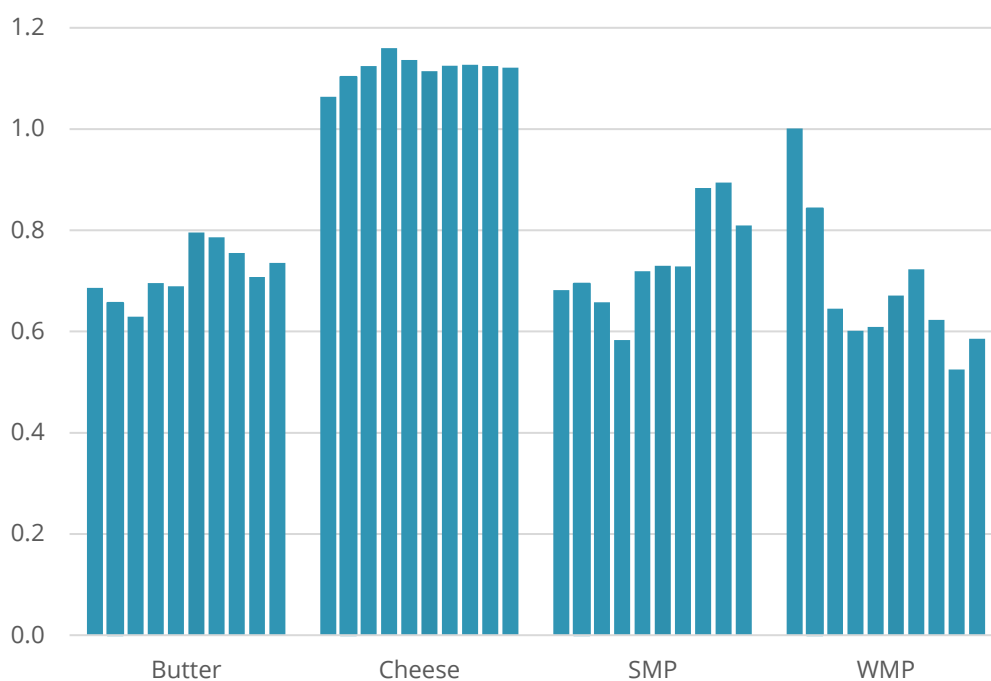
trade costs are commercial costs that are part and parcel of doing business and unavoidable or at least hard to reduce such as stock losses, transport costs and marketing costs.

We use the term trade costs to mean anything that adds costs to trade, whether e.g.

- transport costs

- spoilage or losses

- tariffs

- subsidies

- marketing costs

- language barriers

- variations in product standards

- testing and conformance requirements

- licensing

- certification.

FIGURE 4: PREVALENCE OF SUBSIDY USE BY PRODUCT, 2010-2019
Values greater than 1 mean a product is exported by high subsidy countries bars are ordered from 2010 to 2019.

The trade costs shown in Table 6 are measured relative to domestic trade. A trade cost of 1.0 implies parity with domestic trade costs and a trade cost of 2.0 implies trade costs twice as large as domestic trade costs.

Key points captured in this table are:

- trade costs vary considerably across exporters and rise with distance to market

- trade costs vary considerably by product, reflecting comparative advantages in trade for both fundamental factors (productivity, quality) as well as hidden or explicit policy differences or institutional differences

- subsidies have material effects on trade costs, though these effects can be offset by market access policies like tariffs and FTAs

- policy effects are typically not large enough to alter the relative ranking of exporters in terms of overall height of trade costs (barriers) affecting trade.

Table 6 decomposes trade costs into policy effects measured by our model and other fixed trade costs which, while measured by the model, are not attributable to any particular policies or cause.

The fixed trade costs capture effects of geographic factors like costs of transport, social and cultural barriers, and also policies like quotas or product standards that have not been explicitly included in the model. Unmeasured policy effects includes market-specific differences in the effects of measured policy effects such as additional market access improvements from an FTA beyond the average effect estimated by the model.[15]

Past patterns of foreign direct investment can also influence these fixed trade costs e.g. by lowering costs of doing business due to having a commercial presence.

The fixed trade costs are referred to as fixed because they are effects that are persistent across the period of analysis applying here (2013-2019).[16]

The policy effects in Table 6 are shown as cumulative percentage changes in trade costs on top of the fixed trade costs, leading to the total trade costs.[17] Based on the example in Figure 2, exports of cheese to the US from New Zealand face trade costs that are more than seven times higher than domestic producers in the US and more than twice as high as exports from Australia. Australia's trade costs are lower because it has preferential quota access.

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[15] Were we conducting an analysis of FTAs we would have measured effects for each FTA being studied.
[16] Strictly speaking there is some variation in our fixed trade costs because we have calibrated the trade costs to ensure predicted and actual trade flows match. However, for the countries in this example those adjustments are not large relative to the size of the directional country fixed effects used to estimate fixed trade costs.
[17] Because these effects are shown as cumulative percentage changes the order of the presentation affects the size of the percentage changes. However, this is unavoidable because trade costs are multiplicative.

TABLE 6: EXAMPLE OF TRADE COSTS FOR EXPORTERS TRADING WITH THE USA

Trade costs in 2019 faced by exporters in Canada (CAN), France (FRA), India (IND), South Africa (ZAF), New Zealand (NZL), Australia, (AUS), ordered from left to right by distance to USA.

Product	Cost component	CAN	FRA	IND	ZAF	NZL	AUS
Butter	Fixed trade costs	1.7	2.4	3.2	4.0	4.7	3.2
	Measured policy effects, % change in costs						
	Tariff	0.0%	2.5%	3.2%	0.0%	2.5%	0.3%
	FTA	-1.2%	0.0%	0.0%	0.0%	0.0%	-1.2%
	Subsidy	1.6%	5.0%	2.4%	1.0%	0.7%	1.4%
	Total policy effects	0.4%	7.6%	5.7%	1.0%	3.3%	0.5%
	Total trade costs	1.7	2.6	3.4	4.0	4.9	3.2
Cheese	Fixed trade costs	2.0	1.9	2.5	5.4	7.4	3.4
	Measured policy effects, % change in costs						
	Tariff	0.0%	0.4%	0.4%	0.0%	0.4%	0.1%
	FTA	-8.5%	0.0%	0.0%	0.0%	0.0%	-8.5%
	Subsidy	0.0%	-0.2%	0.0%	0.0%	0.0%	0.0%
	Total policy effects	-8.5%	0.1%	0.4%	0.0%	0.4%	-8.4%
	Total trade costs	1.8	1.9	2.6	5.4	7.4	3.1
SMP	Fixed trade costs	2.3	2.7	1.5	1.3	4.4	7.2
	Measured policy effects, % change in costs						
	Tariff	0.0%	3.5%	3.5%	0.0%	3.5%	0.0%
	FTA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Subsidy	2.5%	6.9%	3.5%	1.7%	1.3%	2.0%
	Total policy effects	2.5%	10.7%	7.1%	1.7%	4.9%	2.0%
	Total trade costs	2.4	3.0	1.7	1.4	4.6	7.4
WMP	Fixed trade costs	1.7	1.4	2.7	4.1	3.7	2.7
	Measured policy effects, % change in costs						
	Tariff	0.0%	3.7%	4.2%	0.0%	3.7%	0.0%
	FTA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Subsidy	2.0%	5.6%	3.4%	1.4%	0.9%	1.6%
	Total policy effects	2.0%	9.5%	7.7%	1.4%	4.7%	1.6%
	Total trade costs	1.7	1.6	3.0	4.1	3.8	2.7

The effect of subsidies varies by product and by export origin. This variation is due to exporting country subsidies (noting that import effects of subsidies are constant). Our estimates suggest that subsidies in France, for example, boost French exports of cheese to the USA (reduce trade costs) but reduce exports of butter, SMP and WMP (increase trade costs).

The finding that subsidies reduce butter, SMP and WMP exports from France suggests that a combination of three effects are occurring, which we cannot disentangle:

- home bias, with subsidies inducing increased domestic trade and expenditure

- negative productivity effects, with subsidies making French milk costs less competitive than they might otherwise be

- substitution towards other dairy products, such as cheese.

In contrast, subsidies have a smaller effect on New Zealand and Australian exporters' trade costs reflecting that subsidies are low in both countries and thus have limited direct effect on trade. In New Zealand's case the 1.7% increase in SMP trade costs is almost entirely due to the effects of US subsidies having a net trade impeding effect.

The effect of FTAs, in reducing trade costs, appears large relative to other policy-related costs albeit of a magnitude that is typical in contemporary research. Notably, the fixed trade costs for exports of cheese from Canada to the US are higher than for exports from France but Canada's FTA with the USA reverses that result in terms of total trade costs.

The model estimates no net effect of FTAs on trade in WMP and SMP, on average. This may be because of exclusions of SMP and WMP, on average, in FTAs or the fact that countries that sign FTAs are typically not specialising in trade of these products so that measured average effects of FTAs are zero or very small.

In the case of Australia's trade costs, we clearly see the effect of preferential market access, beyond the typical effects of an FTA – via the low fixed trade costs in the butter and cheese markets. This is capturing Australia's quota access in both those markets under the Australia-US FTA.

5. Effects of subsidy reform

5.1. Effects on world trade

5.1.1. Summary of average effects

The effects of subsidy reform varies by product market and the kind of subsidy reform undertaken.

In the **milk powder** markets subsidy reform will boost trade, raise producers' factory-gate prices and, on balance, improve consumer welfare globally.[18]

These effects are summarised in Table 7 which shows weighted average percentage changes in exports, producer prices, and the changes in import and export costs that drive the results.

The producer price changes in Table 7 are averages of changes in prices at the factory gate, net of trade (transport) costs, by country.

The export and import cost changes are averages of changes in total world trade costs from the perspective of each country. In general terms, import costs rise with an increase in import demand but export costs fall by more and total trade costs decline.

Removal of amber box and blue box subsidies in OECD countries dominate in terms of effect sizes. The gains from amber and blue box reform change little if spending is shifted into the green box.

The effects of subsidy reform on the **butter** market are similar to that of the milk powder markets but a little more equivocal in terms of variable effects on producer prices, on average. The key difference here is large effects on intra-EU trade when blue box support is removed – estimated to have a large positive effect on intra-EU trade and on extra-EU trade from EU countries.

Subsidy reform has uneven effects across the EU. Removal of subsidies boosts trade from some EU countries, raising producer returns while also reducing their import demand. But on the other side of the coin this means other EU producers have lower export demand and consumers face higher prices for imports.

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[18] The interpretation here of consumer welfare changes is a little muddied by the use of milk powders as a intermediate input. However access to lower cost ingredients can reasonably be expected to lower costs of final consumer goods.

TABLE 7: AVERAGE EFFECTS OF SUBSIDY REFORM IN OECD COUNTRIES
Weighted average percent changes relative to 2019 baseline. Exports weighted by baseline exports. Producer prices and export costs weighted by baseline production. Import costs weighted by baseline expenditure.

Product	Scenario	Exports	Producer prices	Import costs	Export costs
Butter	All subsidies removed	7.1	-0.1	0.3	0.2
	Amber and blue box removed	2.6	-0.3	0.2	0.3
	Green box removed	3.7	0.5	0.2	-0.5
	Shift subsidies to green box	2.4	0.2	0.1	-0.2
Cheese	All subsidies removed	-18.8	-0.9	0.4	1.0
	Amber and blue box removed	-13.5	0.5	0.6	-0.5
	Green box removed	-3.0	-0.2	-0.2	0.2
	Shift subsidies to green box	-13.4	0.5	0.6	-0.5
SMP	All subsidies removed	12.7	4.8	2.2	-5.1
	Amber and blue box removed	8.3	3.3	1.6	-3.5
	Green box removed	3.1	1.3	0.7	-1.4
	Shift subsidies to green box	8.1	3.2	1.6	-3.4
WMP	All subsidies removed	5.8	0.9	-0.1	-0.9
	Amber and blue box removed	4.9	0.9	0.1	-1.0
	Green box removed	0.9	0.0	-0.2	0.1
	Shift subsidies to green box	4.9	0.9	0.1	-1.0

The butter scenario also shows that green box subsidy reform has a larger positive effect on trade than does amber and blue box reform.

Market access barriers in the cheese market mean that subsidy reform – without market access reform – is negative for buyers of cheese. Ignoring the hidden fiscal cost of subsidy payments – that do not show up in prices and are not captured in our analysis – buyers of cheese are shielded from high border prices by the effects of subsidies to domestic producers.

In the cheese market trade costs increase and exports fall. Subsidies are boosting world supply – principally by boosting intra-EU trade and imports of cheese from the EU. When subsidies are removed, high trade costs including market access barriers restrict consumer access to alternative sources of imports. Notably, the EU comprises around half of global cheese demand so EU policies and impacts on EU consumers have a substantial effect on overall global results of policy reform.

Changes in producers' prices are small on average, but that average disguises some significant increases for some producers and declines for others.

Overall, these results are quite variable, reflecting the net result of competing effects across different products and reform scenarios including:

1. which countries are removing subsidies and

    a.   their relative specialization in exporting in importing the product in question

    b.   the structure of their subsidies

2. existing structures of trade and trade costs and whether partners are also reforming subsidies (see 1.)

3. the relative costs of sourcing or selling products elsewhere in the world if supply of imports or demand for exports, from usual places, changes.

Importantly, these results are sector specific. They do not account for fiscal effects from subsidy removal or potentially positive effects from resource allocation. So, they are not statements on total welfare changes.

5.1.2. Distributional effects

The effects of subsidy reform are concentrated in countries with high levels of domestic support and countries that are near countries with high levels of domestic support.

Ultimately, this means that the effects of reform are largest in the EU. This also reflects the fact that EU countries make up around 55% of global dairy trade (including intra-EU trade) and two-thirds of global dairy trade in the products discussed here.

Figure 5 and Figure 6 illustrate the country-specific effects of amber and blue box subsidy elimination and green box subsidy elimination respectively. These charts summarise effects on export and import prices using outward multilateral resistance (OMR) and inward multilateral resistance (IMR). These indices take account of the costs of trade across all countries that a country might sell to (OMR) or buy from (IMR).

Broadly speaking, a decline in multilateral resistance is a good thing. It means lower trade costs. For producers that means higher factory gate prices (other things being equal) and for consumers it means lower cost access to a wider variety of products.

FIGURE 5: AMBER BOX REFORM, CHANGE IN TRADE COSTS BY COUNTRY

Percent change in trade resistance for the top and bottom ten countries by change in outward multilateral resistance (OMR), an index of export costs. IMR is inward multilateral resistance, an index of import costs.
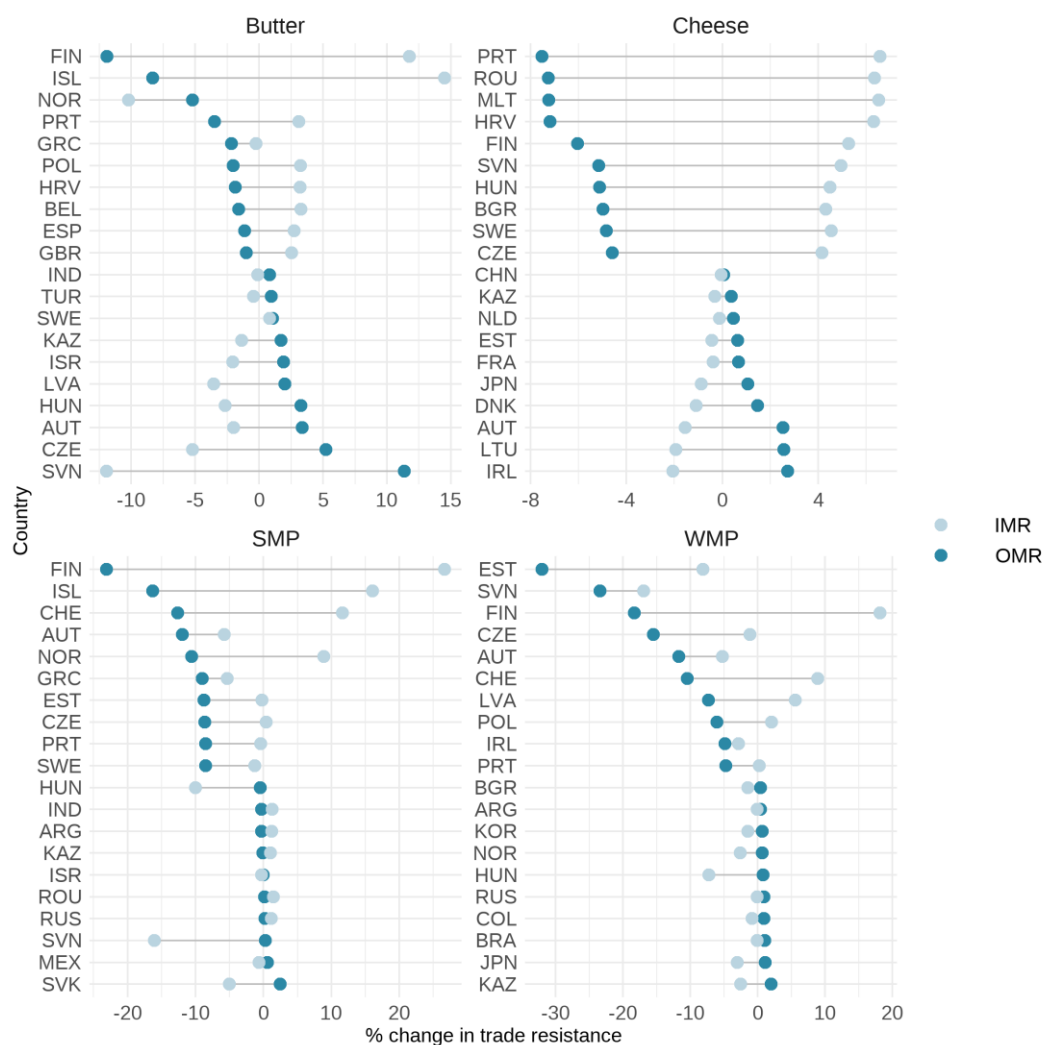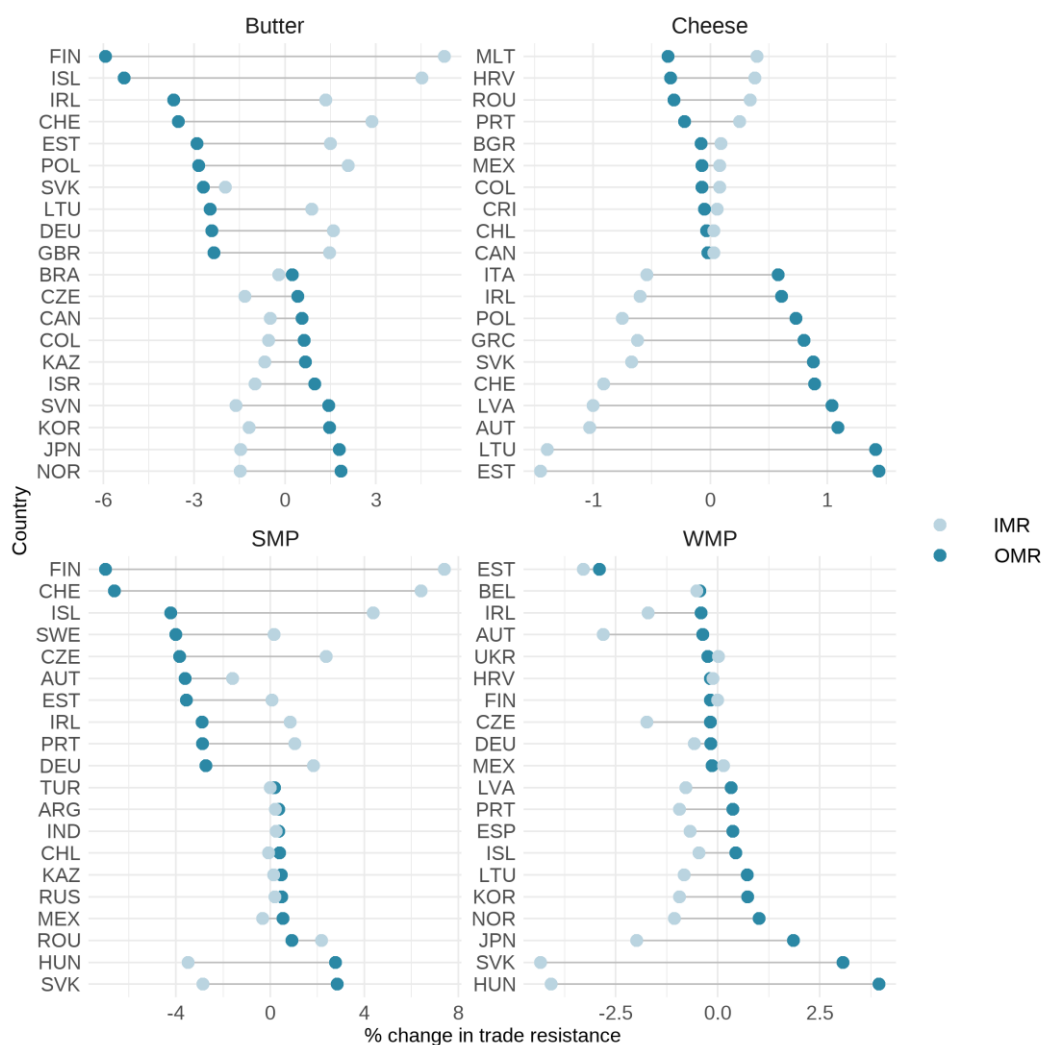
FIGURE 6 GREEN BOX REFORM, CHANGE IN TRADE COSTS BY COUNTRY

Percent change in trade resistance for the top and bottom ten countries by change in outward multilateral resistance (OMR), an index of export costs. IMR is inward multilateral resistance, an index of import costs.

5.2. Effects on New Zealand

New Zealand producers and consumers would benefit from subsidy reform, mainly from removal of amber and blue box subsidies, although there would be some additional benefit from elimination of all subsidies.

The effects vary considerably by product with most of the benefits from expanded trade in SMP where removal of all subsidies would see the value of exports rise by 2.6 percent and factory gate prices rise by 1.8%.

Gains in the butter and cheese market are very small from a percentage change perspective, although the size of trade in those products mean that the income gains, net of trade costs, from elimination of all OECD subsidies are approaching half of the gains in the SMP market.

The effect on trade in WMP is small negative, reflecting that New Zealand's comparative advantage in that market is eroded a little – although the effects are small not least because the majority of New Zealand WMP trade is with countries that are neither major producers of WMP nor significant subsidisers.

Effects for New Zealand are, generally, muted relative to many other markets because existing trade, across all products, is not with the largest spending markets (per capita) or the larger subsidising markets. Indeed the vast majority of New Zealand trade is with countries that are outside the OECD and are much less affected (directly) in these OECD subsidy reform scenarios.

While import demand in countries with high domestic support generally rises following subsidy removal, New Zealand's distance from markets and high trade costs, including market access barriers, means that there are limited gains to New Zealand producers from subsidy reform.

TABLE 8: IMPACTS ON NEW ZEALAND OF OECD SUBSIDY REFORM
Annual impact relative to a 2019 baseline, net effect in 2019 US dollars

| Variable | Scenario | Percent changes | | | | Net effect |
		BTR	CHS	SMP	WMP	USD millions
Prices	Amber and blue box to zero	0.0	0.0	1.4	-0.1	
	Green box to zero	0.0	0.0	0.3	0.0	
	All direct support to zero	0.0	0.0	1.8	-0.1	
	Shift all support to green box	0.0	0.0	1.3	-0.1	
Exports	Amber and blue box to zero	0.2	-0.2	2.6	-0.1	22.4
	Green box to zero	0.0	0.0	0.4	0.1	9.7
	All direct support to zero	0.4	0.5	4.0	-0.2	45.4
	Shift all support to green box	0.0	-0.2	2.6	-0.1	19.5
Income	Amber and blue box to zero	0.2	0.0	2.1	-0.1	19.8
	Green box to zero	0.0	0.0	0.4	0.1	9.5
	All direct support to zero	0.3	0.1	3.2	-0.2	40.8
	Shift all support to green box	0.0	0.0	1.9	-0.1	13.2
Expenditure	Amber and blue box to zero	0.0	0.0	1.9	1.5	2.0
	Green box to zero	0.0	0.0	0.0	0.0	-
	All direct support to zero	0.0	0.1	0.0	1.5	7.6
	Shift all support to green box	0.0	0.0	0.0	1.5	1.0

Appendix 1: Product definitions

DAIRY PRODUCT MODEL DATA SETS PRODUCT GROUPS

HS6 code	Product group	Short name
40210	Skimmed milk powder	SMP
40221	Whole milk powder	WMP
40229	Whole milk powder	WMP
40510	Butter, ghee, anhydrous milkfats	Butter
40520	Butter, ghee, anhydrous milkfats	Butter
40590	Butter, ghee, anhydrous milkfats	Butter
40610	Cheese, fresh cheese, processed cheese	Cheese
40620	Cheese, fresh cheese, processed cheese	Cheese
40630	Cheese, fresh cheese, processed cheese	Cheese
40640	Cheese, fresh cheese, processed cheese	Cheese
40690	Cheese, fresh cheese, processed cheese	Cheese

Appendix 2: From PSE to WTO boxes

OECD data on producer support estimate (PSE) data has been assigned to WTO categories (boxes) as outlined in the table below.

FRAMEWORK USED TO ASSIGN POLICIES TO BOXES

Payment Categories	Basis Detail	WTO category	Exceptions
Payments based on output	Price	Amber - MPS	None
	Output	Amber	None
Payments based on animals, area, income or receipts	Current activity production required	Amber	Green if contains 'Environment', 'Disaster', 'Insurance' but only if not a single commodity transfer (SCT) or group commodity transfer (GCT). Amber if SCT or GCT and with no payment limit.
	Past activity, production required	Green	Data includes indicators for whether payments come with limits on total amount, variable or fixed rates, or input constraints e.g. prescribed farming methods for environmental purposes.
	Past activity, no production required	Green	None.
Payments based on input use	Capital	Amber	Green if contains 'Environment', 'Disaster', 'Insurance' but only if not a single commodity transfer (SCT) or group commodity transfer (GCT).
	On-farm services	Green	Amber if SCT. This may admit SPS programmes as amber, but equally overlooks GCT that may be trade distorting (e.g. animal reproduction programmes).
	Materials	Amber	Green if contains 'Environment', 'Disaster', 'Insurance' but only if not a single commodity transfer (SCT) or group commodity transfer (GCT). Also 'Regional assistance' green if not SCT or GCT.
Non-commodity criteria	Resource retirement	Green	None
	Non-commodity output	Green	None
	Other	Green	None
Miscellaneous payments	Misc	Green	None. A default position pending more precise information.

For this paper we have excluded from analysis any WTO green box support that falls within the OECD's General Services Support Estimate (GSSE). This means the following categories of

spending, mentioned in Annex 2 of the WTO Agreement on Agriculture, are not included in this analysis:

- general services (e.g. research, training, inspection services)

- public stockholding for food security purposes

- domestic food aid.

All other categories of spending listed in Annex 2 of the Agreement on Agriculture are included in the analysis, including decoupled income support.

Appendix 3: Model details

General form of the theoretical model

The general form of the theoretical model is the following system of equations (Yotov et al, 2016 p.74), with time subscripts ignored for simplicity[19]:

$$X_{ij} = \frac{Y_i E_j}{Y} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma}$$

$$\Pi_i^{1-\sigma} = \sum_j \left(\frac{t_{ij}}{P_j} \right)^{1-\sigma} \left(\frac{E_j}{Y} \right)$$

$$P_j^{1-\sigma} = \sum_i \left(\frac{t_{ij}}{\Pi_i} \right)^{1-\sigma} \left(\frac{Y_i}{Y} \right)$$

$$p_i = \left(\frac{Y_i}{Y} \right)^{\frac{1}{1-\sigma}} \left(\frac{1}{\alpha_i \Pi_i} \right)$$

$$E_i = \phi_i Y_i = \phi_i p_i Q_i$$

The first line of the model defines the core of the empirical model:

- X_{ij} is trade between an origin i and destination j.

- The origin country's production is Y_i.

- The destination country's expenditure is E_j.

- Global production is $Y = \sum_i Y_i$.

- Trade costs comprise:

  - bilateral trade costs t_{ij}

  - multilateral export costs Π_i, also known as outward multilateral resistance

  - multilateral import costs P_{ijt}, also known as inward multilateral resistance.

- The trade cost elasticity is σ.

The second and third lines of the model define the multilateral resistance terms.

The fourth equation in the system defines producers' factory gate prices.

The fifth equation follows from assuming that trade balances are exogenous according to an exogenous parameter ϕ, closing the system.

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[19] The derivation of this model begins from micro foundations. Costinot and Rodríguez-Clare (2014) provide a good overview of the micro foundations and assumptions of this and alternative models.

The next two subsections set out the empirical model.

General form of the empirical model

The general form of the empirical model is:

$$X_{ijt} = \exp\left(\eta_{it} + \psi_{jt} + t_{ij}^{1-\sigma}\right) . \epsilon_{ijt}$$

$$t_{ijt}^{1-\sigma} = \sum_L \beta_{rL} . R_{rL} + \delta_{ct} . C_{ct}$$

$$X_{ijt} = \exp\left(\eta_{it} + \psi_{jt} + \gamma_{ij} + \sum_L \beta_{rL} . R_{rL} + \delta_{ct} . C_{ct}\right) + \epsilon_{ijt}$$

The model estimates the value of trade flows (X_{ijt}) from a country, origin i, to a country, destination j, by year (t, for time) based on:

- output effects, labelled η_{it}, that capture average output in a country in each year, averaged over output for domestic trade and for exports by destination, so reflect variations in production conditions at the origin of trade

- demand effects, labelled ψ_{jt}, that capture average annual expenditure in a country in each year, averaged over expenditure on domestically produced products and imports by origin, so reflect variations in demand conditions at the destination of trade

- propensities to trade between pairs of countries (accounting for frictions such as distance) over all years captured in the variable labelled γ_{ij}, where domestic trade $\gamma_{ij=i}$ is typically the reference level (0) for this variable

- a matrix (R_{rL}) of rules and policies (r) affecting trade costs over time, with their effects captured by β_{rL} and L representing a lag structure over the timing of effects of policies – the conceptual basis for those lags is discussed further below while discussing the empirical specification of dynamics

- a matrix (C_{ct}) of other controls on trade costs and associated effects (δ_{ct})

Empirical specification

Specification of bilateral trade costs

Bilateral trade costs are estimated using directional-pair fixed effects (γ_{ij}).Directional-pair fixed effects are pair fixed effects accounting for origin-destination flows e.g. Canada to United States would be one fixed effect and United States to Canada the other fixed effects. This specification allows for asymmetric trade costs, potentially important where, for example, there are substantial otherwise unobserved persistent institutional effects which make trade flow more freely in one direction than another (Beverelli, et al, 2018).

Directional-pair fixed effects provide estimates of bilateral trade costs that do not vary over time and will estimate the effects of all sources of time invariant trade costs such as distance, size, border effects, social and cultural differences etc.

Policy effects on bilateral trade costs

The effects of policies on bilateral trade costs are picked up as deviations from fixed (effect) bilateral trade costs over time.

If bilateral trade costs are measured using fixed effects or other effects (variables) that do not change over time, then policy variables must vary over time. That is, one can only pick up the effects of changes to policies over time.

Identifying the effects of MFN policies, including domestic support, requires data on domestic trade (Heid et al, 2021). Thus, the model includes estimates of domestic trade flows and policy effects on trade are measured relative to domestic effects.

Proxies for multilateral trade resistance

The country-year fixed effects provide the means for estimating the multilateral trade resistance terms for the structural gravity model.

That said, the multilateral resistance terms can only ever be identified as an index relative to something because as an aggregate of bilateral trade costs they cannot (all) be identified directly separately from the bilateral trade costs. We measure the inward and outward multilateral resistances relative to New Zealand's inward multilateral resistance (set to 1).

Other controls

Other non-policy variables used in structural gravity models are there to control exogenous changes in trade costs over time, such as through technological change (whether domestic or multilateral).

We allow for a time dummy that is the same for all countries and takes a value of one for external trade and a value of zero for internal trade. This dummy is used to control for the effects of declining average trade costs globally e.g. due to globalisation.

Model dynamics

The dynamic specification of the model – to account for lags in policy effects on trade - has been informed mainly by theoretical and conceptual considerations and findings in the literature.

Empirical constraints also limit dynamic specifications. These empirical constraints are:

- collinearity, where variable containing the same statistical information, often because they are conceptually related

- the length of the time series in the panel data set, which limits the number of lags that is possible without losing significant numbers of observations of trade flows.

The maximum number of lags has been limited to 3 years. This has been informed by the common use of time intervals of 3 years between observations in panel data analysis of gravity models (Yotov et al, 2016). It has also been informed by the relatively short time period covered by our data set. Where other studies use longer lags, they typically have decades of trade data in their data sets, while the data set used here contains only 10 year's worth of data and thus only 7 years of data after allowing for lags of up to 3 years.

Our empirical model allows for inclusion of consecutive years of data due to the informational value of including additional observations (Egger et al 2021). This differs from many other studies where only every third or fourth or fifth year of data.

Domestic support measures enter the model with export (origin) and import (destination) effects.

Domestic support is expected to have positive effects on exports and negative effects on imports, other things being equal, with the ambiguous net effect on a country's trade (Olper and Raimondi, 2008).

The model allows for a term describing the effect of EU dairy quotas on EU trade with the rest of the world.[20] This variable was included because quotas had a material effect on EU dairy production and global supply response (Jongeneel and Gonzalez-Martinez, 2022).

The impact of the EU milk quotas is, in principle, ambiguous as far as EU exports of manufactured dairy products are concerned. The local effects of the quotas was to reduce milk production and restrict supply of manufactured products for export.

Regional trade agreement effects are admitted with a contemporaneous effect and a 3-year lag. The short-term effects of RTAs on trade are assumed to be captured in the tariff variable. And while the lagged tariff level will also capture some of the lagged effect of RTAs, the inclusion of the lagged RTA variables is there to capture any additional effects from RTAs above and beyond those that would be explained by changes in tariff rates. The literature on effects of RTAs indicate that such effects do exist (Baier et al, 2018), albeit with a lag of three to five years (Egger et al, 2021).

Estimating the multiplicative model

The method for estimating the structural gravity model is a mixture of passion and quasi-poisson GLM. Model testing suggests that the differences in parameter values and model fit, between a poisson GLM and a quasi-poisson are negligible and there are instances where the additional complication of quasi-poisson makes it unusable (principally in policy variable selection).

The estimation follows 4 steps:

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[20] The variable is a binary variable equal to 1 in those years in which EU dairy quotas were in operation. In our data set that is the years 2010 to 2015.

1) a preliminary estimation for selection of trade cost variables and estimated effects of trade policies, using our full panel

   a) using an elastic net poisson GLM on the full "saturated" model with alpha=0.5 and penalties on fixed effects that are one-tenth the penalties on the policy variables

   b) the estimated policy effects are then used as an offset in the next step

2) we estimate origin-year, destination-year and directional pair fixed effects, using PPML , with the trade policy offset (trade costs) from 1)

3) form a single year's baseline model in which we estimate directional pair trade costs for countries with zero trade, using conventional gravity variables to explain our estimated directional pair fixed effects and thus predict those costs for countries without trade flows

4) calibration (estibration) to make predicted trade match actual trade, by adding model residuals back into the model as unobserved trade costs and re-estimating origin and destination fixed effects conditional on trade costs.

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