# Global dairy distortions model

## Model documentation

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# Contents

# 1. Purpose

This report documents the development of a model of global dairy distortions. The model has been created to quantify the effects of governments' policies on international trade in dairy products.

## 1.1. Feedback on model design and development

The purpose of this report is to document model design and development to date.[1] An earlier version of this report was used to prompt feedback and generate ideas for model development and use, such as policies that should be investigated in more detail. The report has been updated where feedback has prompted technical change to the model, including the results of an expert peer review of the model. The report also captures areas of feedback which are potentially relevant for model evolution and development for future case studies.

This report covers:

- high-level model design and objectives
- data and degree of detail contained in the model
- detailed design of the model
- how the model would be used, by way of an example
- areas for further development including through case study analysis.

## 1.2. Illustrate use with simple subsidy reform scenario

To help explain how the model works, we present an illustrative example of a 10 percent reduction in producer support estimates, for countries where we have this data.

This example suggests that untargeted domestic support reform has minimal effect on global trade and welfare, in aggregate. This is due to the competing effects of domestic support on trade – both increasing exports and decreasing imports. It is also due to market access restrictions which are untouched by reductions in domestic support. So while production patterns may be changed by a cut in domestic support, this doesn't necessarily lead to significant changes in exports. However, reform leads to substantial wealth transfers between producers e.g. higher incomes for New Zealand producers and lower incomes for Swiss producers.

## 1.3. More model development to come

[1] Further documentation will follow the completion of a first case study using the model. This will be in the form of model code and a manual for using the model/code.

The model presented here is a prototype rather than a final version. It will be further developed through case studies investigating specific policies or markets.

Given this, the specific model presented here is generic and focusses on aggregate trade in dairy products and high-level impacts of a range of policies, measured in the aggregate.

The model can be applied to specific products such as skim-milk powder or butter or cheese, so that product-specific policy can be investigated.

Further analysis of policies will also be needed, such as tariff-rate quotas and the interaction between tariffs and domestic support.

# 2. High-level model design

The modelling method chosen is called 'structural gravity'. This method was chosen because it best meets the following model-design objectives:

- **global** scope to inform international deliberation on the impacts of policies on producers and consumers around the world
- **rigorous** framework for quantifying effects of policy reform, accounting for complex interactions between countries
- **empirical** evidence of the impacts of existing policies, to assist in the analysing competing claims over the effects of policies
- **complementary** to existing models and methods, to add to the existing suite of models and methods used to analyse effects of dairy trade distortions, such as country-specific models and computable general equilibrium models.

Discussion with stakeholders – including a workshop with industry academics and officials – confirmed that a global perspective will be important for informing international deliberations on subsidy disciplines. A theme in the workshops was the importance of being able to use the model to interrogate proposals for new WTO disciplines or the effects of existing disciplines and flexibilities in the application of domestic support.

Structural gravity has been used extensively in the analysis of international trade, to the point where one expert recently claimed it has celebrity status "because it is constantly applied and extended in thousands of academic papers and policy reports" (Yotov, 2022)[2].

That said, structural gravity has not been widely used for analysing international trade in dairy products or food more generally, though there are a few examples such as a study by Olper and Raimondi (2008) of border effects on food trade within the QUAD countries and a study of global beef trade by Ghazalian et al (2012).

Structural gravity models provide a more rigorous basis for evaluating policy changes than other partial equilibrium models of global trade because structural gravity models can be used to analyse general equilibrium effects and because they account for complex interactions between countries' bilateral trade costs.

Structural gravity models have disadvantages over partial equilibrium models by having less detail around physical relationships. But they make up for this by being highly empirical and internally consistent – with parameters and policy effects estimated with data rather than borrowed from other research.

Computable general equilibrium (CGE) models have advantages over both structural gravity models and partial equilibrium models, by incorporating a wide range of feedback loops,

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[2] See https://voxeu.org/article/gravity-60-celebration-workhorse-model-trade for an accessible review of the development of these models and their advantages.

detailed economic relationships, and adding up constraints. However, CGE models tend to be inflexible, or at least very costly to change, and highly theoretical (as opposed to empirical) unless in the hands of the select few highly skilled CGE modellers in the world.

## 2.1. Structural gravity model in an algebraic nutshell

Structural gravity models arise from the application of micro-economic theory to trade. This theoretical foundation is what gives structural gravity its name, as compared to other gravity models of trade which use size and distance to explain trade – hence gravity – but do not involve consistent application of an underlying conceptual model or theory.

Before providing some intuition, the following sets out the theoretical structural gravity. The model predicts trade between countries ($X_{ijt}$), in a given year ($t$) based on:

(i) The size of an exporting country's production ($Y_{it}$) relative to global production ($Y_t$)

(ii) The size of an importing country's expenditure ($E_{jt}$) relative to global production ($Y_t$)

(iii) Trade costs or frictions.

$$X_{ijt} = \frac{Y_{it}E_{jt}}{Y_t}\left(\frac{t_{ijt}}{\Pi_{it}\mathrm{P}_{jt}}\right)^{1-\sigma}$$

Trade costs comprise three different elements:

- bilateral trade costs ($t_{ijt}$)
- multilateral export costs faced by the exporting country, referred to as outward multilateral resistance ($\Pi_{it}$)
- multilateral import costs faced by the importing country ($\mathrm{P}_{ijt}$)

In the theoretical structural gravity model the impacts of bilateral trade costs are all relative to multilateral costs which are, in turn, a function of bilateral trade costs. This interrelationship poses one of the key empirical challenges in applied structural gravity modelling.

The term $\sigma$ is a trade cost elasticity, translating trade costs into impacts on trade. The trade costs included in this model are all/any costs that cause trade flows to deviate from perfectly matched trade based on comparative advantages and relative preferences for consumption.

## 2.2. Intuition behind the modelling approach

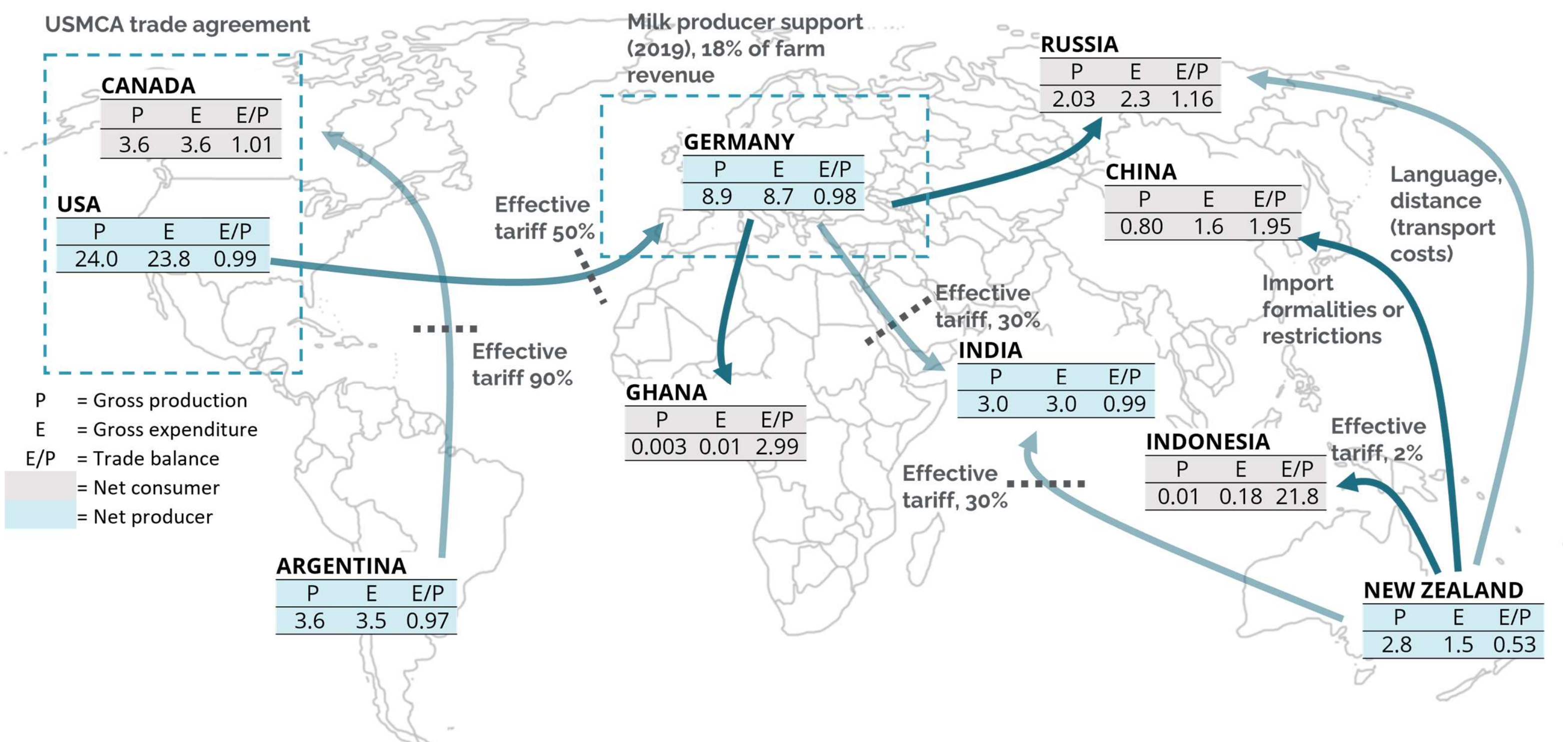
The diagram in Figure 1below provides visual context for the range of effects that the structural gravity model is attempting to pick up. This diagram, along with the following explanations, provides some intuition about the range of interactions that occur between bilateral trade costs and policies and multilateral trade i.e. spill over effects.

### Patterns of trade reflect relative size of production and consumption

The benchmark for trade between countries in a frictionless world is the product of an exporter's share of global production and an importer's share of global consumption – hence the expenditure and production shares in Figure 1.

FIGURE 1: EXAMPLES OF INTERCONNECTED EFFECTS CAPTURED IN STRUCTURAL GRAVITY MODELS

Production and expenditure figures are percent shares of manufactured dairy product value in data set of 111 countries



If there are truly no costs to trade, then there is no particular reason that trade should flow to one country rather than another, except for fundamental differences in the comparative advantage of the exporting country and the size of demand in the importing country.

On this view, if New Zealand produces 1% of the world's cheese and another country consumes 10% of the world's cheese, we would expect New Zealand's exports of cheese to the other country to be 0.1% of world trade (i.e. 1% * 10%) – in the abstract world of no trade frictions.

From an empirical perspective, this approach is predicated on the idea that existing patterns of production and consumption are reasonably strongly correlated with fundamentals affecting the efficiency of production and the scale of local demand, such as climate and human capital.

## Frictions that prevent trade from matching demand and supply

**Distance** is an important predictor of trade costs; however other factors also get in the way of trade flowing from its cheapest location of production to its highest valued use (i.e. the lowest cost matching of supply with demand). Differences in **institutional quality, corruption, or infrastructure** can limit the amount of trade between countries.

Factors that create preferences for trade between groups of countries can also distort patterns of world trade, relative to what simple supply and demand considerations would predict. These factors can, on balance, be positive if they reduce overall trade costs. However, they can also increase trade costs.

**Shared border effects** are an example of a positive effect on trade costs. That is, countries that share a land border tend to trade more with each other than countries that do not – holding distance constant.[3]

Some countries trade relatively intensely with each other, despite the distance between them, because of **social, political and cultural similarities**. For example, countries with a shared colonial history tend to have established institutional ties that mean that they trade more with each other – although this effect tends to decline over time (Head et al, 2010). Similar factors that promote trade include having the **same language** or having **similar legal systems**.

A feature of the structural gravity model is that it seeks to control for all these factors that have permanent or highly persistent effects on trade costs between countries. This is important because it helps to distinguish between trade distortions or costs that are avoidable and those that are not.

[3] One might reasonably assume that distance is always shorter between countries that share a land border than those that do not (at least on average), however the relevant distance measure for understanding trade patterns is one that accounts for distances between major demand and supply centres between countries. Some countries share land borders, but their major cities are long distances from the border.

**Trade policy** is a factor of key interest for understanding trade flows because very often policy is source of avoidable trade costs. Tariffs are an easily observed example of these kinds of costs. **Domestic support** also affects trade costs when it affects output prices.

Having said that, many policy measures are likely to be correlated with non-policy predictors of trade costs. That is, it is difficult to determine whether trade is high between two countries because of permissive policy or policy is permissive because the countries are well-matched for trade from an economic, social, political or cultural perspective. The structural gravity model is constructed to try and disentangle the direction of causation between these effects.

## Relative costs, network effects and trade diversion

Relative costs are ultimately what determines trade flows, in conjunction with relative size (scale of demand and supply). This means that **trade flows between two countries depend not just on policies, distance and relative size of those two countries but also on policies, distance and relative size of all other countries**.

Failure to account for these interdependencies can lead to misleading conclusions regarding how policies affect international trade. This has come to be known as the “Gold medal mistake” of gravity modelling (Baldwin and Taglioni, 2007).

The structural gravity model accounts for these interdependencies by measuring bilateral trade costs relative to multilateral trade costs. In the literature on gravity modelling these are referred to as inward and outward multilateral resistances (Anderson and van Wincoop, 2003).

# 3. Data

The modelling data sets that have been created all follow the same form and scope as the data set summarised in Table 1 below.

The intent in creating the data set was to admit as many countries and years and products as possible. Given data quality issues, however, the data has been limited to 111 countries and to ten years from 2010 to 2019. After we include lagged policy data in the models the number of years of trade data shrinks to 7 years from 2013 to 2019.

## 3.1. Product scope

The main dataset of trade in manufactured dairy products comprises production and trade in: whole milk power (WMP), skim milk powder (SMP), condensed and evaporated milk, butter, cheese, casein, and whey protein concentrate (WPC), referred to here as manufactured dairy products.

Table 7 in the Appendix provides a list of these product groups and the traded products they include, based on harmonised system 6 digit classification (HS6) codes.

This product scope excludes the following dairy products due to extremely sparse or unreliable data on domestic production volumes: yoghurt, buttermilk, lactose and miscellaneous food ingredients.[4]

## 3.2. Trade value

External trade data is sourced from UN Comtrade with a minimum of adjustment. All trade data is in current year US dollars.

Internal trade, the net of production less exports, is estimated using FAO production, use and price tables. The target value is a measure of domestic trade beyond the farmgate, i.e. including some distribution costs.

Internal trade volumes, by FAO products, are estimated using data on commodity use: internal trade volume = production less (feed + non-food uses + processed + stock variation + exports-imports).

[4] A total of ten modelling datasets have been constructed describing production, trade and policies for 9 groups of dairy products plus meat produced from animals that produce milk.

TABLE 1: SUMMARY OF MODEL VARIABLES AND DATA SOURCES, EXAMPLE FOR MANUFACTURED DAIRY PRODUCTS MODEL

| Variable | Type/units | Source | N | Mean | Min | Max | Std deviation |
|---|---|---|---|---|---|---|---|
| Origins/Destinations | ISO, 3 digit alpha code | World Bank, WITS | 111 | | | | |
| Years | Integer | | 7 | | 2013 | 2019 | |
| External trade | US dollar millions | UN COMTRADE | 85,470 | 5.1 | 0.0 | 4,156.8 | 51.6 |
| Internal trade | US dollar millions | FAO, author calculations | 777 | 5,346 | 0 | 160,624 | 16,285 |
| Tariff | % applied (AVE) [5] | World Bank (WITS), author calculations | 85,470 | 0.179 | 0 | 1.271 | 0.238 |
| Non-tariff measures, imports[6] | Count of measures | UNCTAD TRAINS | 85,470 | 125.6 | 0.0 | 532.3 | 105.7 |
| Non-tariff measures, exports | Count of measures | UNCTAD TRAINS | 85,470 | 12.5 | 0.0 | 113.0 | 21.5 |
| Bilateral distance | Kilometres | CEPII | 86,247 | 7,575.5 | 6.7 | 19,812.0 | 4,548.7 |
| Share border | Binary | CEPII | 86,247 | 0.0 | 0.0 | 1.0 | 0.2 |
| Common language | Binary | CEPII | 86,247 | 0.1 | 0.0 | 1.0 | 0.3 |
| Colonial linkages | Binary | CEPII | 86,247 | 0.0 | 0.0 | 1.0 | 0.1 |
| Regional trade agreement | Binary | CEPII | 86,247 | 0.30 | 0.0 | 1.0 | 0.5 |
| EU membership | Binary | CEPII | 86,247 | 0.06 | 0.00 | 1.00 | 0.24 |
| Single commodity transfer | % of farm receipts[1] | OECD | 520 | 0.03 | -4.29 | 0.53 | 0.19 |
| Nominal protection coefficient | % of farm receipts[1] | OECD | 520 | 0.05 | -0.69 | 1.15 | 0.18 |
| Producer support estimate | % of farm receipts[1] | OECD | 520 | 0.06 | -0.62 | 0.48 | 0.11 |

[5] Variables are transformed by natural logarithms i.e. ln(1+rate).
[6] The NTM measures are split by functional grouping, as described in Table 3.

To estimate values of internal trade we map a concordance from 'Use data' items and HS codes, and sum internal trade values to our chosen product groups.

Internal trade value by FAO use item is estimated by taking FAO use volume data (tonnes) as given and multiplying these by prices calculated using, in order of priority:

- domestic price or production value data, where sound, though it generally isn't[7]
- free-on-board export prices obtained either directly or as values over volumes from the UN Comtrade data.

The use of trade data does give rise, occasionally, to nonsensically high prices, and these prices are treated as missing.

Where export prices are not available at all, usually because there are no exports, we use import prices as the benchmark price for internal trade. And if the ratio of the export price to the import price is larger than 2, we adopt the import price as the internal trade price.

Where there are missing values that occur between years with nontrivial internal trade, we assume that the observations are missing, and we interpolate the data linearly.

Additional steps were taken to clean and estimate benchmark prices for milk at the border, given the relative unreliability of export prices as a comparator for a product with low amounts of international trade. Where milk prices were missing we benchmarked prices to those of near neighbours with missing data e.g. estimating Bahamas prices using Jamaica prices.

We also fill missing values within series, where possible, by calculating ratios between farmgate prices and export prices and comparing these to the same ratios for a set of benchmark countries with complete data (USA, Canada, France, New Zealand, Argentina). We then assume that the observed difference between a country's ratio and the benchmark's average ratio persists over time and use that relationship to fill intermittently missing values.

## 3.3. Tariffs

The tariff data we use, from the World Bank World Integrated Trade Solutions website (WITS), are bilateral effectively applied ad valorem equivalents including preferential tariffs. The data is at the HS6 digit level with minimum, maximum and mean values for the range of tariffs being applied at the domestic tariff line level. We use the mean tariff by HS6 classification.

The tariff data has been aggregated from HS6 to product groups using a uniform tariff equivalent – essentially a single tariff which is equivalent, in terms of revenue, as the sum of revenue earned on individual products with different tariff lines.

[7] This is the case for farm-gate milk prices, although we also have to estimate factory gate prices for milk for comparability with trade data so for this we use export FOB prices as the benchmark price for milk that has been transported from the farmgate.

The uniform tariff equivalent provides a more logistically consistent method of aggregating tariffs compared to, say, expenditure weighted averages or simple arithmetic averages.

The formula used for calculating the uniform tariff equivalent (Bach and Martin, 2001) for a product group is:

$$\tau^e = \left(\frac{1-\beta^d}{\sum_i \beta_i\,(p_i)^{1-\sigma}}\right)^{\frac{1}{1-\sigma}} - 1$$

Where the uniform tariff equivalent ($\tau^e$) is a function of the sum of expenditure on products sourced domestically ($\beta^d$), the share of each imported product in the product group's expenditure ($\beta_i$) and the imported products price relative to the price without a tariff ($p_i$), and the trade elasticity ($\sigma$).

This method does require some simplifying assumptions, including an assumption about the rate at which consumers substitute away from imports when prices change i.e. trade elasticities of substitution. For these, we use the global trade weighted average of estimates of product specific trade elasticities at the HS 6 digit level from Fontagné et al (2020). The elasticities are shown in Table 2 and are useful comparisons for the elasticities that are estimated later during the modelling process.

TABLE 2: TRADE ELASTICITIES BY PRODUCT GROUP

| Product group | Estimate |
|---|---|
| Butter | 3.3 |
| Casein | 7.5 |
| Cheese | 6.4 |
| Condensed and evaporated milk | 6.3 |
| Meat | 5.9 |
| Milk | 9.2 |
| Skim-milk powder | 4.5 |
| Whole-milk powder | 6.0 |
| Whey-protein concentrate | 4.3 |
| All manufactured dairy products | 5.0 |

Note too that the tariff data used are ad valorem equivalents that have been estimated and these estimates are contain imperfections, such as approximating the effects of tariff rate quotas. In general, we expect that the treatment of tariff rate quotas would be a useful area for further development of the model and data.

## 3.4. Non-tariff measures

We have classified NTMs into functional groupings, in accordance with similar groupings used in a recent study of NTMs in agriculture by Gourdon et al (2020). A list of the groupings used in the model is set out in Table 3.

Most of the data is from the UNCTAD TRAINS researcher database, updated to include 2019 NTMs using the TRAINS online portal and supplemented by data on contingent import protection (anti-dumping, safeguards, and countervailing duties) from the Vienna Institute for International Economic Studies.[8]

TABLE 3: NTM GROUPS USED IN THE MODEL

| Code | Description | UN MAST classification[9] |
|---|---|---|
| EXP_PRI | Export prices | P3, P5 |
| EXP_RES | Export regulations and restrictions | P6, P9, P1, P2, P4 |
| EXP_SUB | Export subsidies | P7 |
| IMP_COM | Import competition | H1, H9 |
| IMP_CON | Import conformity assessment | A8, A9, B8, B9 |
| IMP_PAY | Import payments | G1, G3, G4, G9 |
| IMP_PRI | Import prices | F1, F3, F4, F6, F7, F9 |
| IMP_PRO | Import contingent protection | D1, D2, D3 |
| IMP_QTY | Import licenses and quotas | E1, E2, E6 |
| IMP_REG | Import regulations | A2, A3, A4, A5, A6, B2, B3, B4, B6, B7, C1, C4, C9 |
| IMP_RES | Import restrictions | A1, B1, C2, C3, E3 |
| IMP_TRI | Import investment | I1, I9 |

Counts of NTMs are used in the model. These counts reflect the average number of NTMs across HS6 digit commodities within each model product group. In the case of overall dairy manufacturing we use the sum of NTMs over all product groups making up manufactured dairy products.

We have chosen not to use ad valorem equivalents (AVEs) of NTMs, at least for this example, even though AVEs are used in other studies (Olper and Raimondi, 2008) and we do have data on NTM price effects from Gourdon et al (2020). The reason for not using them at this stage is to avoid predetermining the effects of NTMs – whether they have a net positive or net negative effect on trade considering the potential trade facilitating effects of some NTMs.[10]

If we wish to look more closely at NTMs in future then we could revisit the specification of NTM variables and consider independent estimates of the trade increasing versus cost increasing effects of NTMs.

[8] https://wiiw.ac.at/wiiw-ntm-data-ds-2.html

[9] https://unctad.org/topic/trade-analysis/non-tariff-measures/NTMs-classification

[10] This decision was supported by the peer reviewer of the model - who has previously worked on a multilateral multi-year academic research project on the effects of NTMs. See Winchester et al (2012). The reviewer agreed with our simple and transparent approach and commented that "the issues of Non Tariff Measures is a perennial problem and one which can take a lifetime to solve".

## 3.5. Producer support measures

Consistent data on domestic support is not readily available at a global level. Consequently we are limited in our choice of comprehensive, consistent and widely available data sources and methods for measuring domestic support.

### 3.5.1. Initial source of data

Our main source of producer support data is from the OECD.[11] Data coverage is limited to 52 countries: 36 OECD[12] countries, seven EU member states not members of the OECD, and nine other non-OECD countries.[13]

The data we have does not, however, include a breakdown for EU member states but rather only includes a single observation for the EU. That being so, we apply the EU average values to all EU member states.

The indicators we use are milk sector:

- **producer support estimates (PSE)**, measuring the annual monetary value of gross transfers from consumers and taxpayers to agricultural producers, measured at the farm-gate level, arising from policy measures that support agriculture, regardless of their nature, objectives or impacts on farm production or income.
- **single commodity transfer (SCT)**, measuring transfers to milk producers from consumers and taxpayers including market price support (both negative and positive).

The intent in selecting these measures is to capture both product-specific support (SCT) and support to the dairy sector more generally (PSE).

Producer support is measured as a percentage of gross farm receipts.

Where we do not have data on domestic support, we set have thus far set the rate of domestic support equal to zero.

### 3.5.2. Expanding measures of domestic support

[11] https://data.oecd.org/agrpolicy/agricultural-support.htm

[12] Austria, Australia, Belgium, Canada, Chile, Colombia, Costa Rica, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

[13] EU Argentina, Brazil, China, India, Indonesia, Russian Federation, South Africa, Kazakhstan, Ukraine. The data includes some observations for the Philippines and Vietnam but these are incomplete for our purposes.

We are expanding our data on domestic support. New measures of domestic support and methods for classifying domestic support will be considered as part of the modelling case studies.[14]

Stakeholders have cautioned that relying on OECD data and classifications could undermine the usefulness of research around WTO disciplines, at least because the labelling and classification of policies represents a language of sorts. WTO classifications/labels are the de-facto language of international negotiations on domestic support disciplines, and they are not the same as the OECD classifications.

Some domestic policies are classified as distortionary by the OECD but non-distortionary according the WTO Agreement on Agriculture. Which kinds of policies are distortive and which are not is is an important point of debate and a candidate for case study analysis with the GDDM.

Thus, to facilitate case study analyses, we are developing additions to our model database on domestic support with:

- measures of domestic support based on WTO notifications, to provide an alternative to OECD data[15]
- expansions of EU domestic support data to include data on EU member countries domestic support
- a concordance between the OECD classifications and WTO classifications.

These database additions, through including WTO notifications, will also expand the number of non-OECD countries for which we have estimates of domestic support. Although the quality of this data will be patchy because not all countries notify domestic support measures and few countries update their notifications regularly.

Experts from industry have also provided us with advice on alternative sources of data and policy information. Some of this data, such as EU country-specific domestic support spending data, is high quality and covers multiple countries and numerous domestic support measures or spending. Other sources of data and insights from industry experts are country-specific or relate to specific policies (e.g. supply management intervention programmes) so will be useful for country- or policy-specific case studies but will not provide generalisable international information.

The database additions will be difficult to complete in a comprehensive way. A new comprehensive database would take many months if not years – degree of difficulty

[14] Our project plan envisaged that the model database would probably need to evolve to serve specific policy questions and to take account of new information or insights during model design and development. In this important respect the model design process is not a one-off.
[15] Note that the OECD data also draws on WTO notifications, so this is not an entirely separate source of data.

corroborated by the absence of a comprehensive detailed international database of domestic support – and such an undertaking is outside scope for this project .

We expect that the database will continue to evolve over time, in terms of detail and country coverage, and additions will need to be prioritised according to case study requirements.

# 4. Model details

## 4.1. 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[16]:

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

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

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

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

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

The first line of the model defines the core of the empirical model. As discussed above in the brief introduction to the modelling framework:

- $X_{ij}$ 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 $\Pi_i$, also known as outward multilateral resistance
    - multilateral import costs $\mathrm{P}_{ijt}$, also known as inward multilateral resistance.
- The trade cost elasticity is $\sigma$.

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 $\phi$, closing the system.

[16] 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.

## 4.2. General form of the empirical model

The general form of the empirical model is:

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

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

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

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 $\eta_{it}$, 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 $\psi_{jt}$, 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 $\gamma_{ij}$, 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 $\beta_{rL}$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 ($\delta_{ct}$)

## 4.3. Empirical specification

### 4.3.1. Specification of bilateral trade costs

Bilateral trade costs are estimated using directional-pair fixed effects ($\gamma_{ij}$) unless this causes empirical problems, such as where trade is sparse, in which case we use pair fixed effects.

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).

Pair fixed effects e.g. one fixed effect for trade flows between Canada and the United States, would pick up average trade costs between partners and where trade costs are symmetric, they will produce the same results as directional-pair fixed effects.

Pair and 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.

On occasion it will be useful to understand the size of effects such as geography on bilateral trade costs. If that is the case, either geographic and institutional variables can be added to the model instead of pair or directional-pair fixed effects. Alternatively bilateral trade costs can be estimated with fixed effects and then a separate regression model can be used to uncover the relative importance of geographic variables and institutional variables on trade costs.

### 4.3.2. 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 ion domestic trade (Heid et al, 2021). Thus, considerable attention is given to including domestic trade flow data in the model, with policy effects on trade being measured relative to domestic effects.

### 4.3.3. 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.

It is usual to measure the inward and outward multilateral resistances relative to another country and this allows for identification of the multilateral resistances.

### 4.3.4. 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).

One common control is the inclusion of 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. Here we include such a variable and label it Globalisation.

Note that controls should not include inflation. The model should be estimated using nominal trade values. Time fixed effects will capture inflation. And direct deflation of values (modelling real trade flows) can lead to spurious regression in structural gravity model estimation (see Baldwin and Taglioni, 2007).

### 4.3.5. 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 includes consecutive years of data. This differs from many other studies where only every third or fourth or fifth year of data is used in the model because of concerns about mis-specifying the effects of policies on trade, which ought to be expected to take time to appear. These concerns are not well motivated, in the sense that policy variables can be lagged to account for delayed effects without losing information by dropping observations and potentially biasing estimates of the duration of policy effects (Egger et al 2021).

In this model, tariffs were assumed to have different effects over time, with an expected negative effect on trade flows in the short term but a potential for a positive effect over time if higher tariffs boost domestic investment and production (Olivero and Yotov, 2008).

The model includes a short term (contemporaneous) tariff effect that can be interpreted as the sensitivity of trade to changes in prices (the trade cost elasticity). A 3-year lag tariffs is used to estimate the dynamic effect of tariffs on trade via domestic investment and output effects. The sum of these two effects provides an estimate of the long run effects of tariffs on trade.

Even if tariffs have been increased in response to a surge in import demand, the effect on prices is still clear – tariffs raise prices paid on imports. And the model's use of importer-year and exporter-year fixed effects controls for endogeneity (reverse causality) with respect to changes in domestic conditions such as good production years and poor production years.

That said, there is an unobservable component to short term tariff changes where tariff rate quotas are in use. Further model development would do well to consider methods for disentangling quantity constraints and tariff effects, that is, to take account of instances where quotas are binding.

The effects of producer support (PSE) on trade are modelled using the same lag structure as tariffs, with a contemporaneous effect and an effect with a 3-year lag.

Unlike tariffs, the effect of PSE in the short term is ambiguous. PSE cannot be interpreted as having a direct effect on prices. Many of the support measures that are counted in PSE do not have a direct effect on prices, even though PSE is presented as a percentage of gross receipts and may therefore seem to be equivalent to a price effect.

In the longer run, PSE is be expected to have positive effects on exports and negative effects on imports, through an expansion of domestic output and investment, much as for tariffs. The overall net effect on a country's trade is ambiguous (Olper and Raimondi, 2008).

In addition to using PSE to measure the effects of domestic support the model includes SCT as a measure of changes in input costs due to domestic support. SCT can be interpreted as having a direct effect on input costs, via transfers to producers, and direct effect on output prices.[17]

For SCT we include a single lagged value of this variable. This specification of a lagged effect on trade is justified by the assumption that transfers to milk producers take time to translate into lower output prices for dairy product manufacturers (all else being equal).

The choice of a different lag structure for SCT avoids problems of collinearity between SCT and PSE. Furthermore, PSE is empirically a better indicator of long term (structural) domestic support trends as it is much more stable than SCT. And PSE captures support not included in SCT.

SCT might be expected to reduce global trade in dairy products overall, by expanding domestic milk production and improving the competitiveness of domestic supply (Ghazalian et al, 2012). However, as for PSE, the net effect is ambiguous because lower domestic input costs can both increase exports and decrease imports.

The model includes a term describing the effect of EU dairy quotas on EU exports to the rest of the world.[18] This variable was included because quotas had a material effect on EU dairy production and global supply response (Jongeneel and Gonzalez-Martinez, 2022).

The counterpart variable for import effects of EU milk quotas is not included in the model due to collinearity.

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.

[17] The directness of this effect relies on assuming a constant mark-up under monopolistic competition.
[18] 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.

Regional trade agreements are included in the model with 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).

### 4.3.6. Interaction terms

The models include interaction terms that make the effects of policies conditional on the levels of other policies.

The effects of tariffs are assumed to be conditional on the rate of domestic support (PSE and SCT). This occurs because if domestic support is very high we would expect the incremental effect of tariffs to be diminished – the domestic cost advantage may make the level of tariffs irrelevant. And this moderating effect is assumed to occur for domestic support – with very high tariffs chilling trade, the level of domestic support matters little in terms of its effect on imports.

An interaction is also included between RTA effects and tariffs. This was motivated by the potential for RTAs to include otherwise unobserved preferential access such as preferential quota allocations. If such an effect exists, then we would expect the interaction between tariffs and RTAs to be negative.

### 4.3.7. Estimating the multiplicative model

The method for estimating the structural gravity model is quasi-poisson GLM (with a log link). It is also called Poisson Psuedo-Maximum Likelihood (PPML). This method is widely considered best practice.[19]

The quasi-poisson GLM is distinguished by:

- linearization of the multiplicative relationships on right hand side of the model via transformation by natural logarithm (hence you have to transform coefficients by exponentials to get the true model value for a parameter)
- the dependent variable (trade flows) remains in level form so that, amongst other things, zero trade flows do not need to be adjusted or excluded, as they would if the entire equation was transformed by natural logarithms
- the variance of the model is assumed to be proportional to its conditional mean which, in a model conditioned on e.g. country-year fixed effects, means that the model accommodates a substantial amount of heteroskedasticity

[19] Widely considered but not universally. Econometricians disagree over whether other methods with alternative assumptions about relationships between variances and conditional means (e.g. quadratic) would be better. But for applied purposes it is the best choice currently.

- the assumption of a variance that is proportional to the conditional mean is, in simple terms, what makes the model quasi/pseudo-poisson. A poisson model, by contrast, assumes that the variance is equal to the mean (following the exact parametric form of a poisson distribution).

# 5. Baseline empirical model

Table 4 presents the results of the econometric model of trade in manufactured dairy products. The coefficient column reports the fitted model coefficient values. The marginal effect column provides the average percentage change in trade flows given a percentage change in the variable after taking account of interaction effects.

The model includes all policy variables hypothesised as influencing dairy trade. This is so that the results can be observed by readers as they are, rather than as curated by the modeller with, for example, sequential and selective removal of statistically insignificant variables. Model specification tests and variable removal will be considered in future development.

### Single commodity transfers have the largest effect on trade

The model suggests that SCT has the largest proportional effects on trade flows with a 1 percent change associated with a 45 percent change in trade flows on average.

The effect of SCT has the expected signs, showing a reduction in imports from an increase in SCT and an increase in exports following an increase in SCT.

Symmetry in the effect of SCT suggests that the effect on global trade is zero, however this is not necessarily the case because these are proportional changes and the overall effect depends on the size of production and demand in origin and destination countries.

### Producer support has a substantial effect on trade, but smaller than SCT

The effects of PSE are much smaller than SCT but are material with a 1 percent change in PSE increasing exports by 7 percent and decreasing imports by an equivalent 7 percent.

PSE is estimated to affect trade flows only over time, with contemporaneous effects being much smaller and highly variable as shown by the fact that the confidence intervals in the 95% CI column being very wide and spanning zero.

### Non-tariff measures estimated to both increase and decrease trade

The effects of non-tariff measures shown in the coefficient column show the average percentage change in trade given one additional non-tariff measure. The effect in the marginal effect column shows the percentage change in trade given a one percent change in the average number of non-tariff measures.

Most of the non-tariff measures are shown to have highly variable effects that have wide confidence intervals that span zero, although most are economically significant in the estimated mean size of effect.

The effects shown in the marginal effect column can be converted to tariff equivalents for comparison with tariffs. Given the estimated marginal effect of tariffs (3.25), the tariff equivalent is approximately one third of the non-tariff measure effect size.

The conformity assessment effect of 0.345 implies that the average level of conformity assessment is equivalent to a tariff of 11 percent. The effects of conformity assessments on imports stand out as being more precisely estimated with a confidence interval that does not span zero.

Import regulations are estimated to increase trade, with an effect equivalent to a tariff reduction of 8 percent. This result is consistent with the findings of Gourdon et al (2020) which found that technical TBT and SPS regulations had positive effects on trade volumes while technical restrictions and conformity assessments reduce trade.

The impact of contingent protection measures and import prices have curiously positive effects on trade, the opposite of what one might expect. Further detailed analysis of NTMs would be required to better understand why these effects are observed. It may be that the contingent protection measure is picking up the introduction of policy in response to changes in trade rather than the other way around.

More generally, the imprecision and statistical insignificance of most of the NTM effect estimates means that most of the effect estimates should be ignored.

### RTAs have trade increasing effects, beyond tariff preferences

RTAs are estimated to increase trade between RTA members by 28 percent. This effect is not very different to the average RTA effect of 34 percent estimated in Baier et al (2019). However the effect estimated here is only for dairy trade and implicitly is additional to the effect that RTA-related tariff preferences have on trade while Baier et al, like many studies, estimates the effects of RTAs using models that do not include tariffs.

### EU milk quotas had the same effect on EU exports as an 8% import tariff

The EU milk quotas that existed prior to 2015 are estimated to have reduced exports of dairy products by 25 percent compared to what they might otherwise have been. The removal of the quotas was equivalent to an average 8 percent reduction in tariffs across EU export markets.

The direct effect of tariffs on trade is not statistically significant. However, the magnitude of marginal effects, after taking account of interactions, is material and consistent with theory and other research. And large standard errors are to be expected given collinearity between tariffs and lagged tariffs. Consequently, we are not troubled by this result in and of itself. Future development will include bootstrapping standard errors of the marginal effects to test whether our degree of comfort is warranted.

TABLE 4: MODEL PARAMETERS

Model includes 627 Origin-Year fixed effects, 630 Destination-Year fixed effects, and 4207 directional country-pair fixed effects. Significance codes: ***=0.001, **=0.01, *=0.05, ^=0.10

| Variable | Coefficient | Std error | 95% CI | Marginal effect |
|---|---|---|---|---|
| Tariff | -0.8385^ | 0.4764 | -1.772; 0.0951 | -3.252 |
| Tariff, t-3 | 0.2891 | 0.5028 | -0.6964; 1.275 | 0.921 |
| Import conformity assessment | -0.0092* | 0.0044 | -0.0179; -0.0005 | -0.345 |
| Import regulations | 0.0050^ | 0.0027 | -0.0004; 0.0103 | 0.271 |
| Import restrictions | -0.0010 | 0.0097 | -0.0200; 0.0179 | -0.018 |
| Import contingent protection | 0.0444 | 0.0532 | -0.0600; 0.1488 | 0.324 |
| Import prices | 0.0219^ | 0.0126 | -0.0029; 0.0467 | 0.074 |
| Import competition | 0.2750 | 2,772.2 | -5,433.1; 5,433.6 | 0.054 |
| Import quantity | 0.0136 | 0.0097 | -0.0055; 0.0326 | 0.066 |
| Export restrictions | 0.0038 | 0.0157 | -0.0270; 0.0346 | 0.037 |
| Export subsidies | 0.2603*** | 0.0131 | 0.2346; 0.2860 | 0.016 |
| Export prices | 0.0122 | 0.0139 | -0.0152; 0.0395 | 0.034 |
| EU milk quotas, exports | -0.2832*** | 0.0616 | -0.4038; -0.1626 | -0.247 |
| RTA t-3 | 0.2770** | 0.1063 | 0.0687; 0.4853 | 0.284 |
| PSE, exports | -0.4167 | 2.243 | -4.813; 3.980 | -0.530 |
| PSE t-3, exports | 7.455*** | 1.300 | 4.908; 10.00 | 7.159 |
| PSE, imports | -0.1520 | 2.426 | -4.907; 4.603 | 0.144 |
| PSE t-3, imports | -7.321*** | 0.9761 | -9.234; -5.408 | -6.747 |
| SCT t-1, exports | 45.35*** | 0.1984 | 44.96; 45.74 | -45.525 |
| SCT t-1, imports | -45.77*** | 0.1999 | -46.16; -45.37 | 45.357 |
| Globalisation, 2013 | 0.0986 | 387.4 | -759.2; 759.4 | -- |
| Globalisation, 2014 | 0.1533 | 387.4 | -759.1; 759.4 | -- |
| Globalisation, 2015 | 0.0163 | 387.4 | -759.3; 759.3 | -- |
| Globalisation, 2016 | 0.0194 | 387.4 | -759.3; 759.3 | -- |
| Globalisation, 2017 | -0.0292 | 387.4 | -759.3; 759.3 | -- |
| Globalisation, 2018 | 0.0090 | 387.4 | -759.3; 759.3 | -- |
| Globalisation, 2019 | 0.0367 | 387.4 | -759.3; 759.3 | -- |
| Tariff t-3 : RTA t-3 | -0.1346 | 0.2049 | -0.5361; 0.2670 | -- |
| Tariff : PSE imports | 1.470 | 1.930 | -2.313; 5.253 | -- |
| Tariff : PSE exports | -0.5628 | 0.5452 | -1.631; 0.5058 | -- |
| Tariff : SCT t-1 imports | 1.190 | 0.8753 | -0.5258; 2.905 | -- |
| Tariff : SCT t-1 exports | 0.0525 | 0.0954 | -0.1345; 0.2396 | -- |
| Tariff t-3 : PSE imports t-3 | 2.893* | 1.418 | 0.1133; 5.673 | -- |
| Tariff t-3 : PSE exports t-3 | -1.494^ | 0.7712 | -3.005; 0.0178 | -- |

# 6. Simulated impacts of reducing PSE

## 6.1. Policy reform specification

To simulate the effect of reducing PSE we adopt a simplified assumption of a 10 percent reduction across all countries with PSE rates greater than zero.

We apply this de facto reform as a percentage reduction rather than a percent change reduction. That is, a PSE of 0.5 falls to 0.45 rather than 0.40. This means that the simulation preserves relative levels of PSE prior to the reform, for those countries with PSE rates greater than 0.

The hypothetical reform scenario is applied to both current PSE and PSE lagged by 3 years – as if PSE was always 10 percent lower than actually observed.

## 6.2. Impact analysis, approach

The effects of trade policy reform can be broken into 4 steps with each step accounting for a progressively wider scope economic adjustment and feedback effects (Yotov et al, 2016; Anderson et al, 2018; Anderson et al, 2020):

1. direct effects of changes in trade costs on trade between reforming countries, known as the partial equilibrium effects
2. multilateral effects on import and export prices, known as conditional general equilibrium effects, where changes in bilateral trade costs affect trade costs globally
3. changes to producer prices and resulting changes to trade, output and expenditure, holding productive capacity constant; referred to as an endowment general equilibrium
4. full general equilibrium effects with changes in productive capacity via e.g. changes in investment.

In this example we consider only the first 3 of these 4 steps. Step 4 is excluded for two reasons. The first is that this is a sectoral model and full general equilibrium analysis requires a complete model of the economy. The second is that accounting for investment effects, in addition to our simulation, could also result in double counting because the gravity model contains dynamic terms (lagged policy effects) which imply investment effects captured in the model itself.

In future this issue could be revisited, with the objective of identifying reasonable and robust ways to identify investment effects. Anderson et al (2020) found that accounting for dynamic investment effects increased the effects of trade liberalisation by a multiplier of 1.8.

Below we discuss the first two steps and the third step separately, summarising the results and how they have been constructed. The methods are also discussed in more detail in Yotov et al (2016) and Anderson et al (2018).

## 6.3. Direct effects on trade costs and trade

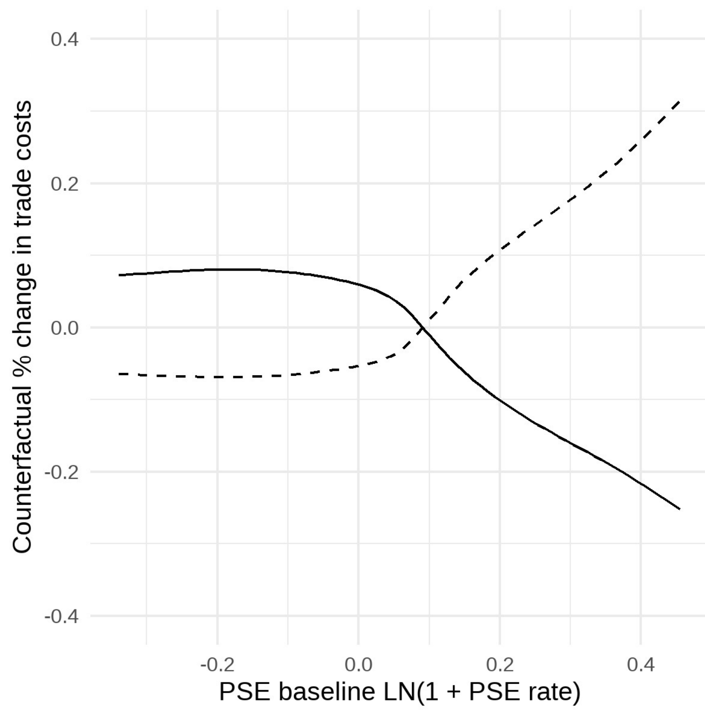
### 6.3.1. Small effects overall, net of many increases and decreases

Overall, the direct effects of the reform are a modest 0.1 percent increase in the value of trade[20], a 0.8 percent reduction in import costs[21] and a 0.8 percent increase in export costs.[22]

These are the effects coming from steps 1 and 2 of the analysis set out above.

The relatively small effect of the 10% reduction in PSE arises directly from the offsetting effects of the reform on trade costs, with lower PSE reducing import costs and increasing export costs as shown in Figure 2.

FIGURE 2 CHANGES IN TRADE COSTS WITH A 10 PERCENT REDUCTION IN PSE
Smoothed means. Dashed line is relationship to level of PSE in exports. Solid line is relationship to PSE in imports. There is substantial variation around these relationships given the pre-reform level of trade costs such as from tariffs and RTAs.




[20] Average percentage change in exports weighted by baseline exports.
[21] Average percentage change in import costs weighted by baseline expenditure.
[22] Average percentage change in export costs weighted by baseline production.

### 6.3.2. Largest effects found in places where producer support is constraining trade

Country-specific effects of on trade are summarised in Table 5 for a selection of countries chosen to show a range of effects. A full set of results is available in the appendix.

The country-specific results show larger effects for countries that have a high rate of PSE and are located in regions of the world where PSE is relatively high. For example, producers in Norway (NOR) and Switzerland (CHE) may lose some state support when PSE is reduced and consequently some export competitiveness, but this is offset by increased demand for their exports from other countries lowering domestic support. Meanwhile, domestic demand for domestically produced products declines. Consequently, both imports and exports increase.

The results show that consumer import costs in Norway and Switzerland increase, implying higher consumer prices, at least relative to the United States. The index used to measure the incidence of import costs is relative to the import costs of the USA (set to 0). Higher consumer import costs reflects increased imports from countries with higher trade costs, such as without tariff preferences.

TABLE 5: DIRECT EFFECTS ON TRADE OF A 10% REDUCTION IN PSE BY COUNTRY
Percent change, counterfactual versus baseline. Import cost and export cost changes are changes in indices of relative costs of trade, with USA trade costs the benchmark.

| Country | Exports | Imports | Import costs | Export costs |
|---|---|---|---|---|
| Argentina | 0.16 | 0.19 | 1.6 | -1.5 |
| Australia | 0.14 | 0.17 | 1.3 | -1.3 |
| Brazil | 0.08 | 0.07 | 0.9 | -0.9 |
| Canada | 0.27 | 0.19 | -0.1 | 0.1 |
| Denmark | 0.03 | 0.09 | -1.6 | 1.7 |
| Germany | 0.05 | 0.05 | -1.6 | 1.7 |
| Honduras | 0.00 | 0.00 | 1.6 | -1.6 |
| India | 0.07 | 0.07 | 1.6 | -1.6 |
| Indonesia | 0.19 | 0.01 | -2.7 | 2.6 |
| Ireland | 0.03 | 0.10 | -1.6 | 1.6 |
| Italy | 0.18 | 0.20 | -1.7 | 1.7 |
| Japan | 0.88 | 0.32 | -4.7 | 4.8 |
| Malaysia | 0.07 | 0.02 | 1.5 | -1.6 |
| Mexico | 0.65 | 0.12 | -0.1 | 0.1 |
| New Zealand | 0.01 | 0.18 | 1.4 | -1.4 |
| Norway | 0.97 | 0.94 | -6.8 | 7.3 |
| Republic of Korea | 0.03 | 0.01 | -5.1 | 4.8 |
| Russian Federation | 0.20 | 0.04 | -0.6 | 0.6 |
| Senegal | 0.00 | 0.00 | 1.5 | -1.5 |
| Switzerland | 0.92 | 1.27 | -6.2 | 6.6 |
| Togo | 0.00 | 0.00 | 1.5 | -1.6 |
| United States of America | 0.20 | 0.23 | 0.0 | 0.0 |
| Viet Nam | 0.00 | 0.00 | 1.5 | -1.6 |

In contrast, for a country like New Zealand there is a very small increase in trade as New Zealand is far from most markets and especially those where PSE is high and impeding imports.

### 6.3.3. Calculation of direct trade and trade cost effects

The direct effects on trade follow from the marginal effects of our econometric model and are calculated by:

- estimating bilateral trade costs for all countries based on:
    - model estimated trade costs, equal to the sum of the policy effects and directional country pair fixed effects estimated in the model described in Table 4
    - predicted trade costs, for country-pairs with zero trade flows, based on a regression of model estimated trade costs on common institutional and geographic variables: distance, contiguous borders, colonial relationships and common official language
- selecting the most recent year, in the data, to represent the baseline i.e. 2019
- using the estimated bilateral trade costs, along with origin and destination fixed effects, in a PPML model of 2019 trade to predict baseline trade, pre-reform[23]
- calculate counterfactual, post-reform, trade costs by reducing PSE in the data by 10% and recalculating trade costs by recalculating the policy component of the trade costs using the coefficients in Table 4
- using the calculated post-reform bilateral trade costs, along with origin and destination fixed effects, in a PPML model of 2019 trade to predict counterfactual trade.

## 6.4. Impacts on producer prices and real incomes

### 6.4.1. Small overall changes in trade and producer prices

The policy reform effects remain small overall, after accounting for changes in producer prices and expenditure and incomes.

The value of global trade increases only very slightly (0.001 percent). However, this largely reflects the assumption that global production capacity does not increase, only relative prices, so that the global distribution of trade and the costs of trade change but the availability of products do not change.

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[23] A necessary step to remove noise (errors) from the model so that simulated reform effects reflect only estimated policy effects and not noise.

The size of country-specific changes are significant, even though the increases and decreases balance each other out from a global perspective.

The effects on sector incomes, by country, are indistinguishable, at least in nominal terms, from the change in producer prices.[24] That being so, the changes in prices shown in Table 6 indicate that producer support causes nontrivial wealth transfers between producers globally. Producers in countries with low PSE rates face higher prices (incomes) while producers in countries with high PSE rates face lower prices (incomes).

TABLE 6: EQUILIBRIUM EFFECTS ON TRADE OF A 10% REDUCTION IN PSE BY COUNTRY ACCOUNTING FOR PRICE AND INCOME CHANGES

Percent changes between reform scenario and baseline

| Country | Exports | Imports | Import costs | Export costs | Producer prices |
|---|---|---|---|---|---|
| Argentina | 2.8 | -1.6 | 1.2 | -1.4 | 1.1 |
| Australia | 1.3 | 0.6 | 1.1 | -1.2 | 1.0 |
| Brazil | 0.8 | 1.3 | 0.9 | -0.9 | 0.7 |
| Canada | 0.9 | -0.9 | -0.1 | 0.1 | -0.1 |
| Denmark | -1.5 | -1.3 | -1.2 | 1.5 | -1.2 |
| Germany | -1.6 | -1.3 | -1.2 | 1.4 | -1.1 |
| Honduras | 1.3 | 1.1 | 1.6 | -1.6 | 1.3 |
| India | 2.4 | 0.2 | 1.2 | -1.4 | 1.2 |
| Indonesia | -0.3 | -2.2 | -2.7 | 2.3 | -1.8 |
| Ireland | -0.6 | -1.2 | -1.3 | 1.5 | -1.2 |
| Italy | -1.3 | 1.3 | -1.2 | 1.4 | -1.1 |
| Japan | -3.2 | -0.5 | -4.0 | 4.7 | -3.6 |
| Malaysia | 1.5 | 1.4 | 1.6 | -1.7 | 1.4 |
| Mexico | 1.4 | -0.3 | -0.1 | 0.1 | -0.1 |
| New Zealand | 1.8 | 0.3 | 1.3 | -1.5 | 1.2 |
| Norway | -5.7 | 1.6 | -5.4 | 6.7 | -5.0 |
| Republic of Korea | -3.8 | -1.9 | -4.7 | 4.7 | -3.6 |
| Russian Federation | 1.3 | 1.3 | -0.4 | 0.5 | -0.4 |
| Senegal | 2.1 | -0.9 | 1.2 | -2.0 | 1.6 |
| Switzerland | -6.2 | 2.8 | -4.4 | 5.6 | -4.3 |
| Togo | 1.9 | 1.8 | 1.6 | -2.0 | 1.6 |
| United States of America | 1.3 | -0.2 | 0.0 | 0.0 | 0.0 |
| Viet Nam | 1.5 | 2.9 | 1.9 | -1.8 | 1.5 |

Changes to producer prices are a key determinant of future investment. That being so, countries with price increases could be expected to increase their productive capacity. That is, while this implementation of the model does not go on to quantify these effects, the price

[24] In other, non-sector, analyses, real income effects can be determined by deflating income changes by changes in import costs. However, this calculation has ambiguous meaning in a sectoral model such as this because it relies on the idea that producers will be having to purchase imports (capital equipment, intermediate goods) subject to import costs. This interpretation can apply to some dairy trade but will not apply in cases where trade in intermediates is very low.

changes also provide the indication of where production capacity is likely to expand if producer support is reduced.

### 6.4.2. Calculation of impacts on prices and incomes

Calculating effects on prices and incomes involves solving the non-linear system of equations set out in the theoretical model in section 4.1.

To do this we follow the iterative procedure outlined in Yotov et al (2016) and Anderson et al (2018) which uses PPML to solve for multilateral resistance terms and progressively updates the terms of the system to converge, rather than use a non-linear solver.[25] We follow this method based on guidance in Felbermayr and Yotov (2021, footnote 12, p.7) that it is the simplest to apply and that the method delivers approximately the same result as using a non-linear solver.

The iterative algorithm using PPML does not always converge, however, especially with large widespread policy shocks. That being so, we anticipate using a non-linear solver to test the equivalence of methods with large changes. It may be simply that very large policy charges are methodologically difficult to assess and may necessitate splitting the solver algorithm into a sequence of smaller sized shocks.

[25] Implementation of this algorithm was also greatly assisted by copying large chunks of code from this R implementation https://r.tiid.org/R_structural_gravity/ by Mauricio “Pachá” Vargas Sepúlveda.

# 7. Model development

## 7.1. Response to peer review

The model details and results discussed above remain as they were in our initial model design report.

However, following peer review, some of the technical details in the model code have changed to fix issues identified by the reviewer. The changes will not be perceptible to readers of this report as they relate to technical points of detail in the empirical implementation or to methods for variable selection that are only material for future, non-illustrative, applications.

Estimates of the econometric models' parameter standard errors have been corrected by properly applying quasi-poisson pseudo maximum likelihood where previously the modelling was applying poisson maximum.[26]

Methods for simulating general equilibrium effects have been improved to minimise the occurrence of non-convergence. The peer reviewer confirmed, with sensitivity analyses, that the simulations may fail to converge. This issue may persist and require ongoing attention as solutions to non-linear systems of equations have no single closed form solution and require numerical simulation so will always be sensitive to e.g. starting values and solution methods.

The peer reviewer suggested a series of model (variable) selection methods, including Bayesian approach or elasticnet methods, and cautioned against step-wise selection methods. Our intent in presenting the model examples above was to demonstrate a range of effects by including many variables without much in the way of selection effects. So, we have not revisited the scope of the illustrative models presented in this report. However, we have expanded the modelling code to include the recommended frequentist (elasticnet) methods for model selection and these will be available for use in case study analyses and by other model users when the model code is released for wider use following the completion of the first case study.

## 7.2. Case study development

The modelling approach described above promises a very useful basis for quantifying observed effects of policy distortions on global dairy trade and has been endorsed by stakeholders and the peer reviewer. There are, however, many options for further development and improvement.

The main factor affecting model development is decisions about policy reform case studies and question-specific refinements required.

[26] The distinction being that quasi-poisson allows for a dispersion parameter which as has the effect of allowing the variance of distribution differ from the mean.

Workshops and discussions with stakeholders have thus far pointed us in the direction of several possible case studies that would be of valuable to end users of the research, and which answer questions of ongoing debate or concern e.g.

- what sorts of modalities should be pursued to improve WTO disciplines on domestic support
    - should specific policy measures be targeted for reform, on the grounds that they have disproportionately distortive effects or?
    - does the scale of fiscal support or number of measures matter more, from a global perspective, than the effects of some specific measures?
    - which countries have the most distortive domestic support policies, overall and does this therefore mean that market-specific commitments or disciplines matter more than commitments on particular policy measures?
- do market access barriers materially reduce potential gains from reforms to domestic support measures?
- how accurate are the WTO Agreement on Agriculture's presumptions about some policies being non-distortionary?
    - do higher shares of spending on green-box measures result in reduced distortions to global dairy trade?

Industry appears somewhat more interested in country-specific and policy-specific analyses than are officials and academics. An example of this is the supply intervention programmes in the EU which caused considerable concern about suppression of commodity prices in 2019.

In our view it would be sensible to devote a case study to country-specific policies to illustrate that sort of application of the model.

That said, we tend to the view that first case study ought to be somewhat more general, so that it can answer questions of more general interest in the first instance.

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# Appendix Tables

TABLE 7 DAIRY PRODUCT MODEL DATA SETS PRODUCT GROUPS

| HS6 code | Product group | Group code |
|---:|---|---|
| 40110 | Liquid milk and cream | MLK |
| 40120 | Liquid milk and cream | MLK |
| 40130 | Liquid milk and cream | MLK |
| 40140 | Liquid milk and cream | MLK |
| 40150 | Liquid milk and cream | MLK |
| 40210 | Skimmed milk powder | SMP |
| 40221 | Whole milk powder | WMP |
| 40229 | Whole milk powder | WMP |
| 40291 | Condensed and evaporated milk | CON |
| 40299 | Condensed and evaporated milk | CON |
| 40410 | Whey protein concentrates | WPC |
| 40490 | Whey protein concentrates | WPC |
| 350220 | Whey protein concentrates | WPC |
| 40510 | Butter, ghee, anhydrous milkfats | BTR |
| 40520 | Butter, ghee, anhydrous milkfats | BTR |
| 40590 | Butter, ghee, anhydrous milkfats | BTR |
| 40610 | Cheese, fresh cheese, processed cheese | CHS |
| 40620 | Cheese, fresh cheese, processed cheese | CHS |
| 40630 | Cheese, fresh cheese, processed cheese | CHS |
| 40640 | Cheese, fresh cheese, processed cheese | CHS |
| 40690 | Cheese, fresh cheese, processed cheese | CHS |
| 350110 | Casein | CAS |
| 350190 | Casein | CAS |

TABLE 8: ALL COUNTRIES, DIRECT EFFECTS OF A 10% REDUCTION IN PSE

| Country | Exports | Imports | Import costs | Export costs |
|---|---:|---:|---:|---:|
| United States of America | 0.2 | 0.2 | 0.0 | 0.0 |
| Afghanistan | 0.0 | 0.0 | 1.5 | -1.6 |
| United Arab Emirates | 0.0 | 0.0 | 1.5 | -1.6 |
| Argentina | 0.2 | 0.2 | 1.6 | -1.5 |
| Australia | 0.1 | 0.2 | 1.3 | -1.3 |
| Austria | 0.0 | 0.0 | -1.6 | 1.7 |
| Belgium | 0.0 | 0.0 | -1.6 | 1.7 |
| Benin | 0.0 | 0.0 | 1.5 | -1.5 |
| Burkina Faso | 0.0 | 0.0 | 1.5 | -1.6 |
| Bulgaria | 0.1 | 0.1 | -1.6 | 1.7 |
| Belarus | 0.1 | 0.2 | 1.6 | -1.6 |

| Country | Exports | Imports | Import costs | Export costs |
|---|---|---|---|---|
| Bolivia | 0.0 | 0.0 | 1.5 | -1.5 |
| Brazil | 0.1 | 0.1 | 0.9 | -0.9 |
| Barbados | 0.0 | 0.0 | 1.5 | -1.6 |
| Botswana | 0.0 | 0.0 | 1.5 | -1.6 |
| Canada | 0.3 | 0.2 | -0.1 | 0.1 |
| Switzerland | 0.9 | 1.3 | -6.2 | 6.6 |
| Chile | 0.1 | 0.1 | 1.1 | -1.2 |
| China, mainland | 0.8 | 0.0 | -1.1 | 1.2 |
| Cote d'Ivoire | 0.0 | 0.0 | 1.5 | -1.6 |
| Colombia | 0.3 | 0.2 | -0.9 | 0.9 |
| Cabo Verde | 0.0 | 0.0 | 1.5 | -1.6 |
| Costa Rica | 0.0 | 0.0 | 0.1 | -0.3 |
| Cyprus | 0.0 | 0.0 | -1.6 | 1.6 |
| Czechia | 0.1 | 0.1 | -1.7 | 1.7 |
| Germany | 0.0 | 0.1 | -1.6 | 1.7 |
| Denmark | 0.0 | 0.1 | -1.6 | 1.7 |
| Ecuador | 0.0 | 0.0 | 1.5 | -1.6 |
| Egypt | 0.0 | 0.0 | 1.5 | -1.5 |
| Spain | 0.1 | 0.0 | -1.6 | 1.7 |
| Estonia | 0.1 | 0.1 | -1.6 | 1.7 |
| Finland | 0.0 | 0.1 | -1.6 | 1.6 |
| France | 0.0 | 0.1 | -1.6 | 1.7 |
| United Kingdom | 0.0 | 0.0 | -1.6 | 1.7 |
| Gambia | 0.0 | 0.0 | 1.5 | -1.6 |
| Greece | 0.1 | 0.0 | -1.6 | 1.6 |
| Grenada | 0.0 | 0.0 | 1.5 | -1.6 |
| Guatemala | 0.0 | 0.0 | 1.6 | -1.6 |
| Guyana | 0.0 | 0.0 | 1.5 | -1.6 |
| Honduras | 0.0 | 0.0 | 1.6 | -1.6 |
| Croatia | 0.2 | 0.2 | -1.7 | 1.7 |
| Hungary | 0.3 | 0.2 | -1.7 | 1.7 |
| Indonesia | 0.2 | 0.0 | -2.7 | 2.6 |
| India | 0.1 | 0.1 | 1.6 | -1.6 |
| Ireland | 0.0 | 0.1 | -1.6 | 1.6 |
| Iceland | 0.5 | 0.5 | -6.8 | 6.9 |
| Israel | 0.0 | 0.0 | -1.2 | 1.0 |
| Italy | 0.2 | 0.2 | -1.7 | 1.7 |
| Jamaica | 0.0 | 0.0 | 1.5 | -1.6 |
| Jordan | 0.0 | 0.0 | 1.5 | -1.6 |
| Japan | 0.9 | 0.3 | -4.7 | 4.8 |
| Kazakhstan | 0.1 | 0.1 | 1.5 | -1.6 |
| Kyrgyzstan | 0.0 | 0.0 | 1.5 | -1.5 |
| Cambodia | 0.0 | 0.0 | 1.5 | -1.5 |
| Republic of Korea | 0.0 | 0.0 | -5.1 | 4.8 |
| Sri Lanka | 0.0 | 0.0 | 1.6 | -1.6 |

| Country | Exports | Imports | Import costs | Export costs |
|---|---|---|---|---|
| Lithuania | 0.2 | 0.3 | -1.7 | 1.7 |
| Luxembourg | 0.0 | 0.0 | -1.8 | 1.7 |
| Latvia | 0.1 | 0.2 | -1.7 | 1.7 |
| Morocco | 0.0 | 0.0 | 1.5 | -1.6 |
| Mexico | 0.7 | 0.1 | -0.1 | 0.1 |
| Malta | 0.0 | 0.0 | -1.7 | 1.6 |
| Myanmar | 0.0 | 0.0 | 1.5 | -1.5 |
| Mauritania | 0.0 | 0.0 | 1.5 | -1.6 |
| Mauritius | 0.0 | 0.0 | 1.6 | -1.6 |
| Malaysia | 0.1 | 0.0 | 1.5 | -1.6 |
| Nicaragua | 0.0 | 0.0 | 1.6 | -1.6 |
| Netherlands | 0.0 | 0.1 | -1.6 | 1.7 |
| Norway | 1.0 | 0.9 | -6.8 | 7.3 |
| New Zealand | 0.0 | 0.2 | 1.4 | -1.4 |
| Pakistan | 0.0 | 0.0 | 1.5 | -1.6 |
| Peru | 0.1 | 0.0 | 1.5 | -1.5 |
| Poland | 0.0 | 0.1 | -1.6 | 1.7 |
| Portugal | 0.3 | 0.2 | -1.7 | 1.7 |
| Paraguay | 0.0 | 0.0 | 1.6 | -1.6 |
| Russian Federation | 0.2 | 0.0 | -0.6 | 0.6 |
| Saudi Arabia | 0.1 | 0.1 | 1.5 | -1.6 |
| Senegal | 0.0 | 0.0 | 1.5 | -1.5 |
| El Salvador | 0.0 | 0.0 | 1.5 | -1.6 |
| Suriname | 0.0 | 0.0 | 1.5 | -1.6 |
| Slovakia | 0.1 | 0.1 | -1.7 | 1.7 |
| Slovenia | 0.1 | 0.1 | -1.7 | 1.7 |
| Sweden | 0.1 | 0.0 | -1.6 | 1.7 |
| Togo | 0.0 | 0.0 | 1.5 | -1.6 |
| Thailand | 0.1 | 0.0 | 1.5 | -1.5 |
| Tunisia | 0.1 | 0.0 | 1.5 | -1.6 |
| Turkey | 0.2 | 0.3 | -3.2 | 3.3 |
| Uruguay | 0.1 | 0.2 | 1.6 | -1.6 |
| Viet Nam | 0.0 | 0.0 | 1.5 | -1.6 |
| Zimbabwe | 0.0 | 0.0 | 1.5 | -1.5 |

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