The (non-)Price We Pay for Non-Tariff Measures: A practical and novel method to incorporate empirical estimates of the price-effect of technical non-tariff measures into a computable general equilibrium model.

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Abstract

Trade policy, including non-tariff measures (NTMs), could play a vital role in balancing interconnected domestic and international priorities. Existing literature empirically estimating the effect of NTMs on prices often involves complicated mathematics or does not estimate the effect of marginal changes in NTMs. This paper utilises the latest, innovative datasets to design a simple estimation strategy for considering the price-effect of NTMs. The robustness of this econometric estimation is hampered by a lack of observations of non-tariff measures; thus, it is recommended future research uses NTM datasets with more observations. Nevertheless, this research proposes novel methodology to incorporate the price-effect of NTMs within a Computable General Equilibrium (CGE) model - via the price wedge between the prices of imported and domestically produced products. However, this methodology is flawed because there is no direct theoretical link between NTMs and domestic prices. So, this paper recommends a consultation of NTM policy and trade modelling experts to design a more theoretically robust method of incorporating empirical estimations of NTMs' price-effect within a CGE model.

Acknowledgements

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1. Introduction

As the interactions between economic, environmental and geopolitical priorities become ever more complex, governments will need to take increasing care in how they use economic policy levers, such as trade policy, to achieve intertwining domestic and international objectives. For instance, international trade incentivises countries to specialise in the production of goods they have a comparative advantage in. The improvement in productive efficiency arising from this specialisation can increase output and thus global economic development. However, this can increase the use of certain inputs in a region, increasing associated environmental degradation.

'Non-tariff measures' (NTMs) is a concept that encompasses all policy measures (other than tariffs) that have an economic effect on international trade (WTO, 2022). These are largely controls that restrict the type and quantity of imports into a country. This paper focuses on technical NTMs, types of NTMs which do not primarily aim to affect trade but do so anyway. An example of these are Sanitary and Phytosanitary (SPS) measures, which regulate the safety of food imports as well as plant and live animal imports.

Typically, NTMs are considered to be trade-impeding – i.e. causing fewer imports and higher import prices which can lead to less international trade and greater global inefficiency. For example, regulations on the chemicals used to preserve fruit may cause exporters to change the chemicals they use. This increases the price of imports of fruit into the UK which increases the UK's overall price level of fruit.

The most recent literature considers alternative implications of NTMs. This paper takes a behavioural approach by theorising that the imposition of technical NTMs may increase consumers' trust in imports (causing their demand for imports to increases) (Beghin & Xiong, 2018). Greater imports may decrease domestic prices.

One approach to quantify NTMs is to consider the effect of them on prices. Empirical estimations of the *price-effect* of NTMs tend to involve complicated mathematics to derive required price series. This can disengage policymakers. To rectify this, the research in this paper adapts existing methodology by Cadot and Gourdon (2014). They utilise World Bank price level indices (PLIs) to negate the need for multiple price series to estimate the marginal effect of NTMs on prices.

The effects of changes to trade policy are often analysed using computable general equilibrium (CGE) modelling. These models simulate a simplified global economy. The GTAP framework model, commonly used in the literature, is used in this paper. It is a perfect competition model so imposes strong price-taking assumptions on the relationships between economic agents.

CGE models can be heavily criticised for their simplistic treatment of non-tariff measures. NTMs are generally treated as 'iceberg costs' within the GTAP framework. This means liberalisation of NTMs within the models can be interpreted as a reduction in the costs of transporting goods between countries. This reduces the price wedge between prices of domestically produced goods and imports. This paper proposes a more empirically informed treatment of NTMs within a CGE model.

Food security, a country's ability to maintain the availability of food to all its citizens (including during exogenous shocks), is economically and geopolitically linked to trade policy. Thus, this paper will demonstrate its proposed methodology for empirically incorporating NTMs within a CGE model by exploring their effect on the self-sufficiency and affordability of food.

This paper tests the hypothesis that liberalisation of NTMs reduces consumers' trust in imports. This reduces imports which increases domestic market prices. This may increase countries' self-sufficiency and reduces the affordability of food.

In summary, this paper investigated the viability of new methodologies to both simplify empirical estimation of NTMs' price-effect and incorporate this empirical estimated price-effect of NTMs into a CGE model. These are presented in *Methodology & Result I* and *Methodology II* respectively. These methodologies are informed by literature and theory explored in the *second chapter*. Finally, *Results and Discussion II* show the benefits of applied general equilibrium analysis of NTMs by demonstrating how the proposed modification to the CGE model can be used to investigate NTMs' effect on food security.

2. Literature and Theory

This chapter discusses the literature and theory that has influenced methodological decisions leading to the novel methodologies within this paper.

Discussion on quantifying the effects of non-tariff measures (NTMs) in the past two decades stems from Deardorff and Stern's (1997) work. They introduce three broad methods for quantification: *frequency-based*, *price comparison* (or price-effect) and *quantity-impact* - though several years later Gebrehiwet (2004) expands this to seven approaches.

Frequency-based measures, such as the frequency index series used in this paper, is the only approach which measures NTMs by observation. These series are the most comprehensive sources of global NTMs publicly available.

However, this approach does not quantify any economic effect. Furthermore, Deardorff and Stern (1997) highlight measurement bias as a further flaw of *frequency-based* measures. Given the vast volume and variety of NTMs countries impose, it is very difficult for data collectors to accurately note which measures apply to every single trade flow. Therefore, *frequency-based* measures may not be entirely accurate. Moreover, this accuracy is likely to be systematically worse for NTMs imposed by lower income countries as they are less likely to accurately report their NTMs. This can introduce measurement bias into estimation – especially in the methodology demonstrated in this paper where data is skewed towards lower income countries.

Investigation of Andriamananjara et al.'s (2004) work amongst others', reveals some attempts at the *price-effect* approach can quickly become complicated. This is because it requires two sets of prices to understand the price wedge NTMs drive between imports and exports. Rarely is this price data available in the required format which leads to complicated mathematics, underpinned by strong assumptions, to derive them. This can lead to methodologies that are difficult to understand for more generalist economists, including those that directly advise policymakers. This reduces the influence of analysis conducted which utilises this approach. Furthermore, Santeramo and Lamonaca's (2019) work found that studies on the effect of NTMs using two set of prices were more likely to produce lower and less significant results.

Therefore, this paper looks to Cadot & Gourdon's (2014) methodology (inspired by Kee, Olarreaga and Nicita's (2008) - which estimates the price wedge by controlling for all other factors that could affect it). This paper builds on Cadot & Gourdon's (2014) estimation of ad-valorum equivalents (AVE) (the price-effect of existing NTMs) by estimating the marginal impact of changes in NTMs. However, this paper still suffers from the same limitations outlined in the literature, including: omitted variable bias due to only considering one subcategory of NTMs at a time; and the assumption that domestically produced and imported goods are perfectly substitutable (Beghin & Xiong, 2018) (Ferrantino, 2006).

Jager and Lanjouw argue the crux of the *quantification question* is regarding NTMs' effect on quantity of imports (Jager & Lanjouw, 1977) (Stern & Deardorff, 1997). Using prices as a proxy is problematic because the relationship between prices and imports is complicated by trade, demand and supply elasticities. However, the econometrics of a *quantity-impact* approach is also imperfect. It tends to estimate NTMs as residuals or dummies in assumption-ridden models (such as Gravity models). Other unobserved factors may be included in residuals biasing estimates of NTMs. Importantly for this research, changes in relative prices drive changes in the quantity of imports demanded in the GTAP CGE model. This means any modification to the CGE model regarding NTMs must maintain a relationship between NTMs and prices to ensure NTMs affect the quantity of imports.

Andriamananjara et al. (2004) incorporated an econometrically estimated effect of NTMs on prices into a CGE model via the price wedge between imported and exported goods. The intuition is NTMs impose compliance costs on exporters increasing the gap in prices between those goods imported into a foreign market and the market's domestically produced goods. This reduces the price competitiveness of exports in foreign markets. Assuming a downwards sloping import demand function, this reduces the quantity of goods imported.

This price wedge concept works no matter the direction of the price-effect of NTMs. Therefore, this approach is employed in this paper by adding a "change in SPS frequency index" variable between household-facing prices of imported and domestically produced goods. This itself extends Andriamananjara et al.'s (2004) work by giving a detailed explanation of how the CGE model is modified to incorporate this extension - Andriamananjara et al. (2004) give little indication into how they have modified their CGE model.

However, this research challenges Andriamananjara et al.'s (2004) intuition (originating from Deardorff and Stern's (1997) stylized facts). More recent literature, such as Hernandez's (2019) work, critiques the bias in literature towards this narrow view of NTMs. Hernandez (2019) states technical NTMs are often imposed to internalise social and environmental externalities which may outweigh price-raising effects. For example, without regulations on trade, imported food may be of such a low standard it increases a state's healthcare costs. These costs would be borne by all taxpayers (including those outside the food importing market). In welfare economics, this means the marginal social benefit of consuming imported food is lower than the marginal private benefit. Then, the introduction of Sanitary and Phytosanitary (SPS) measures may have a net benefit on society (despite causing higher prices which reduces consumer surplus).

This paper extends Hernandez's (2019) welfare reasoning further by developing behavioural reasoning from Beghin & Xiong (2018). Consumers may, explicitly or implicitly, recognise that some of these costs to themselves, and society, of consuming imported food are not included in prices. Thus, consumers may have greater trust in imported goods with greater technical NTMs as these measures may form part of consumers' heuristic decision-making. For example, if consumers consider import standards to be generally 'high' they may think imported food is safer for consumption. This could increase the demand for imports. Assuming imports are cheaper than domestically produced goods, this may decrease domestic market prices. Santeramo and Lamonaca's (2019) literature review also found that studies were more likely to find that technical NTMs increase trade compared to other types of NTMs. Within a CGE model, this would reduce the price wedge between domestic and import prices which would increase trade.

3. Data

A constructed cross-sectional dataset is used to regress prices on the incidence of NTMs as well as country-specific, product-specific and country-product-specific control factors. *This chapter* describes the characteristics of, and issues using this dataset.

<u>NTMs</u>

This research uses the same frequency-based proxy of NTMs, *frequency ratios*, as Cadot & Gourdon (2014) from the UN Conference on Trade and Development (UNCTAD)'s Trade Analysis Information System (TRAINS) dataset. *Frequency ratios* measures the proportion of tradable products within a product group which have at least one NTM applied to them (World Bank, 2012).

As the author of this paper could only access the data via the World Bank's World Integrated Trade Solution (WITS) software, frequency ratios that were obtained could not be disaggregated further than three broad, agri-food product groups. The groups are: animal-related agri-food goods; vegetable-related agri-food goods; and food products.[1] This limits the number of observations in the dataset which reduces the number of control variables that could be used. This may overestimate the strength of the relationship if excluded variables are correlated with explanatory variables. Furthermore, both Andriamananjara et al. (2004) and Deardorff & Stern (1997) advocate for considering NTMs at the most granular level possible to mitigate against the variety of NTMs and the diversity of impacts (even the same NTM can have on different impacts on different products).

Countries within the dataset tend to have most of their products within a given product group covered by at least one Technical Barrier to Trade (TBT) or SPS measure as shown by the

[1] See *Appendix A* for these product groups mapped to the Harmonised System coding regime

mean and skewness reported in *Table 1*.[2] Furthermore, the small standard deviation for TBTs is consistent with the World Bank's finding that *the incidence* of technical measures is not correlated with countries' income (World Bank, 2018). (However, this paper finds *the effect* of NTMs on prices is correlated with countries' income).

Table 1: Descriptive statistics for frequency indexes of SPS measures and TBTs. Countries range from having no products, within a product group, subject to technical NTMs ('0'), to all products within a product group facing an NTM ('100')

	Frequency Index	
	Sanitary and Phytosanitary Measures	**Technical Barriers to Trade**
Mean	79.4	63.6
Median	93.2	86.2
Standard Deviation	30.6	0.6
Skewness	−1.6	−0.7
5th percentile	4.3	0
95th percentile	100	100

Prices

Price level indexes (PLIs) of food are obtained from the World Bank's International Comparison Program (ICP) dataset. This data series enables a direct comparison of prices. PLIs demonstrate whether x units of a currency, which can buy y units of product z in *Country* A, could buy an equal quantity of product z in *Country* B once the initial currency is converted to that of *Country* B.[3] These prices are relative to the world average. This negates the need to use complex mathematics to derive the price series to estimate the price gap between import and world prices as older papers have done.

12 categories of food, beverage and tobacco prices were mapped to the three NTM product groups using ICP sectoral category names and Harmonised System chapter-level descriptions.[4]

Generally, lower income countries have lower PLIs than higher income countries because lower income countries' consumption baskets contain a greater proportion of goods (relative to services) – generally, goods are cheaper than services. And, as there are more lower income countries in the dataset than higher income countries, both GDP per capita and PLIs in the dataset follow a positively skewed distribution. Gross domestic product per capita is therefore one of the country-specific factors used to isolate the effect of NTMs on prices. Other controls to account for differences between countries' prices and the world price are given in *Table 2*.

[2] TBTs are regulations on the characteristics of imported products (World Bank, 2018)
[3] For further explanation see Rao (2013)
[4] The sectors in the price data could not be more precisely mapped as sector are constructed on a bespoke basis for each country depending on their expenditure bundle (World Bank, 2005)

Control Variables

Table 2: Control Variables

Control Variable	**Country-** (r) **or Country-Product Group-** (ir) **Specific**	**Description**	**Source**
Tariff Rates[5]	ir	Most favoured nation (MFN) tariff rate; obtained at chapter level and simply weighted; latest available year	*Market Access Map, ITC*
Import Dependency	ir	Constructed ratio of imports to domestic supply; thousands of tonnes; mapped using item name and HS chapter description; average of 2010 to 2020	*Food Balance Sheet, FAO*
GDP	r	GDP per capita; PPP USD 2015 constant prices; average of 2012 to 2017	*World Development Indicators, World Bank*
Development Ranking	r	Human Development Index (HDI) ranking; 2017	*UN Development Programme*
Transport Costs	r	Transport prices; PLI world average = 100; same aggregation procedure as food PLIs; 2017	*International Comparison Program, World Bank*
Labour Costs[6]	r	Average monthly earnings in the agriculture, forestry, and fishing sector; PPP USD 2017 constant prices; 2017	*Wages and Working Time Statistics, ILO*
Energy Prices[7]	r	Diesel fuel pump prices; USD per litre; 2016	*World Development Indicators, World Bank*

[5] Aggregated effective tariff rates (rates *actually* applied which are lower for countries with trade agreements) would have been preferred. Andriamananjara et al. (2004) also initially used simply weighted MFN rates to reduce resource-intensive data processing

[6] For two countries with no agricultural labour costs in the source data, agricultural labour costs were assumed to be 70.4% of the average of economy-wide monthly earnings (based on the observed relationship between agriculture and economy-wide monthly earnings in the data). For countries with no labour costs at all in the source data, an average of monthly earnings was taken of nearby countries with similar demographic characteristics and levels of GDP per capita and development

[7] For countries with no 2016 fuel price data, data from 2014 or 2010 was used instead

4. Methodology & Results I: NTMs and Prices

Equation 1 describes the specification used to estimate the price-effect of non-tariff measures (NTMs) for agri-food product groups to, eventually, incorporate into a computable general equlibirum (CGE) model. An OLS estimator was choosen instead of WLS or other similar estimators. This is because: a cross-sectional dataset was used; the modelling broadly meeting classical assumptions of ordinary least squares (OLS); and this paper's aim to keep estimation as simple (and thus understandable and repeatable) as possible.

Equation 1: Specification

$$\begin{aligned} \boldsymbol{lnAgriFoodPrices_{ir}} \\ = \boldsymbol{\beta_0} + \boldsymbol{\beta_1 lnNTMFrequencyRatio_{ijr}} + \boldsymbol{\delta_{ir}} + \boldsymbol{\delta_r} + \boldsymbol{A_i} + \boldsymbol{V_i} \\ + \boldsymbol{u_{ir}} \end{aligned}$$

Where, δ_{ir} are country-product group specific factors, δ_r are country-specific factors and A_i and V_i are binary dummy variables which take a value of 1 for the animal-related product group and vegetable-related product groups repectively. NTM variables are indexed over country, NTM type (i.e. Technical Barriers to Trade (TBTs) or Sanitary and Phytosanitary (SPS) measures) and product group. u_{ir} is the idiosyncratic error.

This chapter dicusses methodological nuances and issues in estimating *Equation 1*. The *last subsection* gives a rationale for the provisional results estimated. This informs how the empirical estimation can be incorporated into the theory-driven computable general equilibrium (CGE) model in *Methodology II*.

Prices

Using agri-food prices weighted simply, rather than by expenditure, tended to improve the explanatory power of models by around $ten\ percentage\ points$. This is because NTMs are applied to imported goods. So, NTMs may have a greater influence on the prices of goods which are imported in larger quantities than on goods which consumers spend more of their income on.[8] [9]

Non-Tariff Measures

'NTM frequency index' was interacted with development ranking. Importing individuals and firms in countries with greater institutional trust, governance and cultural attitudes (as associated with HDI ranking) may respond differently to changes in the standards of imported goods relative to countries with a lower development ranking. This interaction also reduces collinearity with GDP per capita.

The dummy for vegetable-related products, V_i, was consistently postive and signficicant. This shows these products have a higher price, controlling for regressors, relative to animal-related products and other food products. For example, farming of vegetable products tends to be more

[8] This could be tested by regressing expenditure weights on the regressors
[9] Import weighting could not be used due to an inability to robustly map imports to prices

labour-intensive than other food groups. Assuming labour costs are generally higher than intermediate input costs, this could explain why vegetable-related products may have higher prices that other agri-food goods. Thus, to improve the explanatory power of the model, observations for vegetable products were removed from the estimation procedure in order to remove excess noise.[10]

Protecting Degrees of Freedom

Given the low number of observations (around 115 for animal and food product groups), effort was taken to reduce the number of variables to maximise degrees of freedom to improve the robustness of estimation.

Labour costs acts as a proxy for productivity, capitalisation, and export intensity. Fuel pump prices acted as a proxy for composite energy prices before they were removed as its coefficient was insignificant and added no additional explanatory power to the model. Development ranking acts as a proxy for food aid dependency and subsidy regimes.

The technical barriers to trade (TBT) variable was removed as it added no additional explanatory power to the model – it was rarely significant in outputs reported by Cadot & Gourdon (2014).

Tariff Rates and Simultaneity Bias

The tariff rate variable has a strong theoretical link to prices but proved difficult to estimate (Cadot and Gourdon (2014) also failed to get a significant result). Graphically, tariff rate only seemed to be correlated with prices when interacted with import dependency - see

[10] There were too few observations to robustly estimate a separate regression for vegetable products

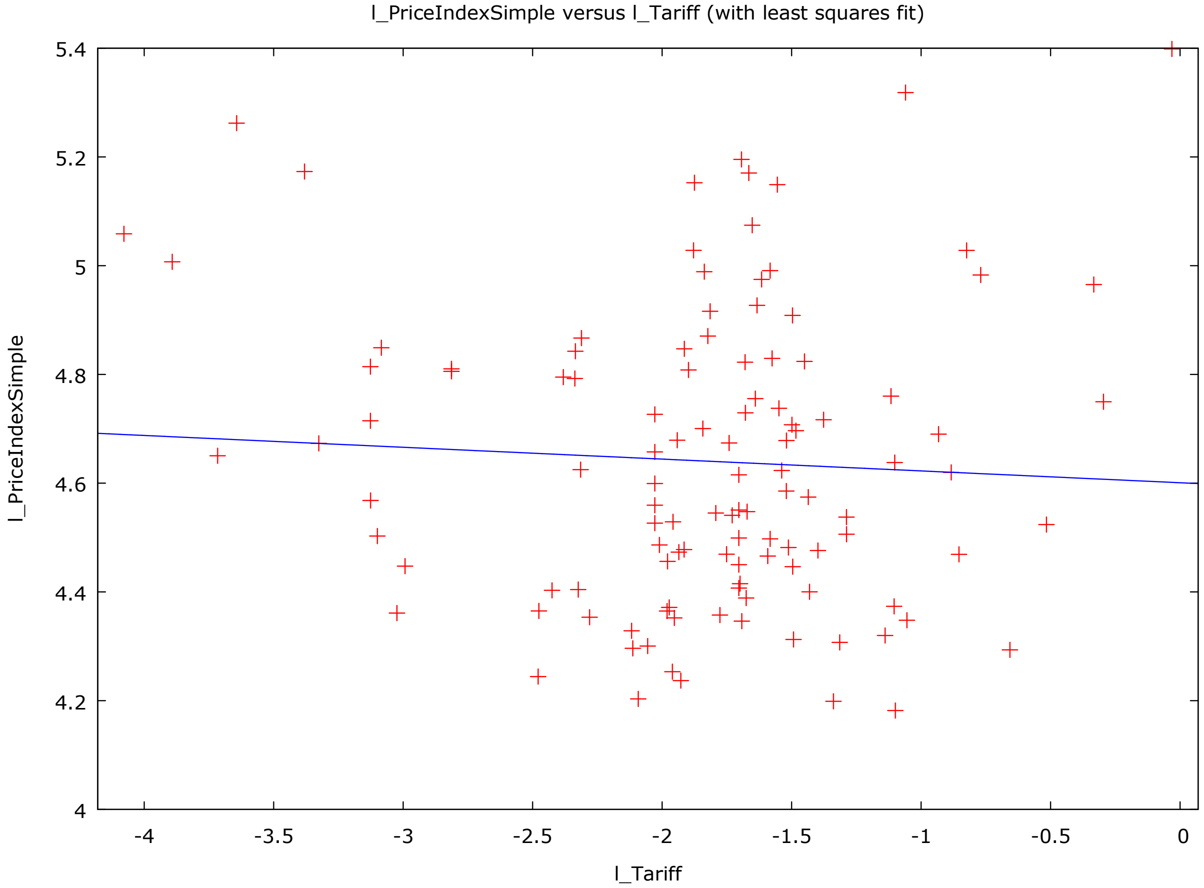
l_PriceIndexSimple versus l_Tariff (with least squares fit)
l_PriceIndexSimple
l_Tariff
5.4
5.2
5
4.8
4.6
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Figure 1 *and*

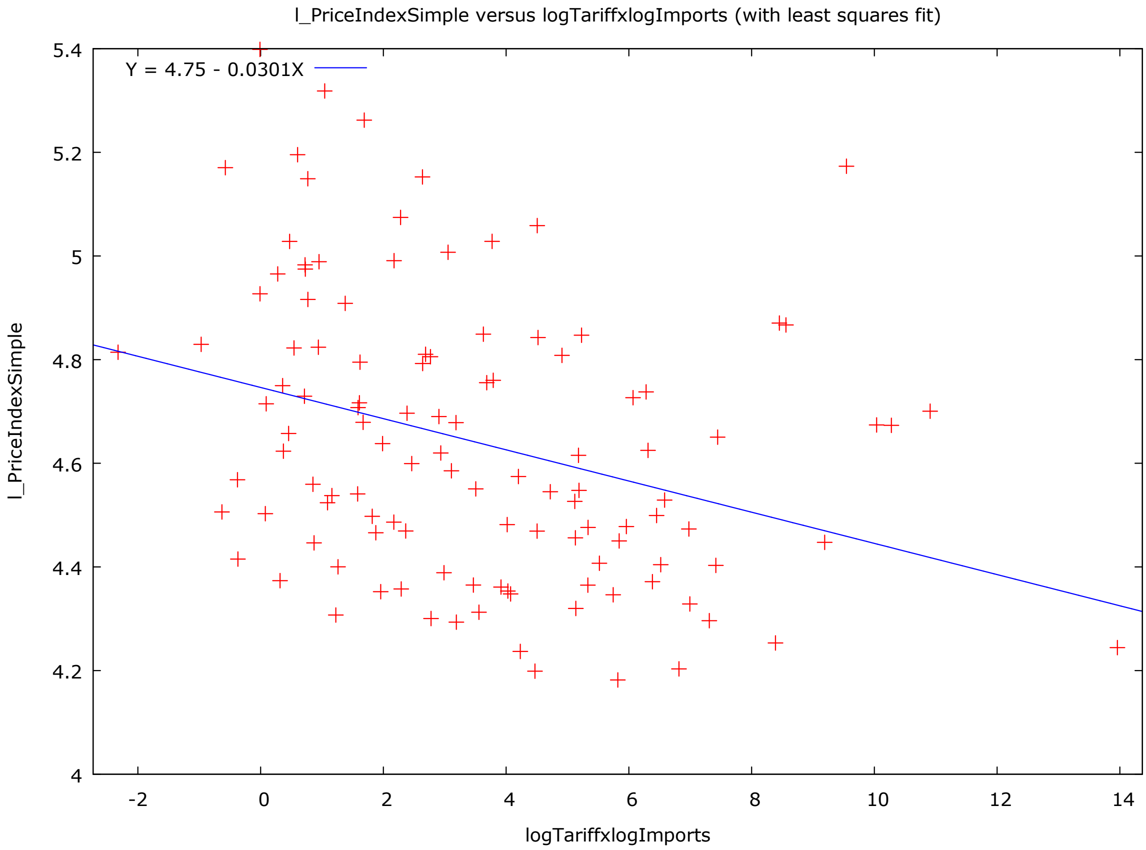

Figure 2. Thus, import dependency was interacted with tariffs.

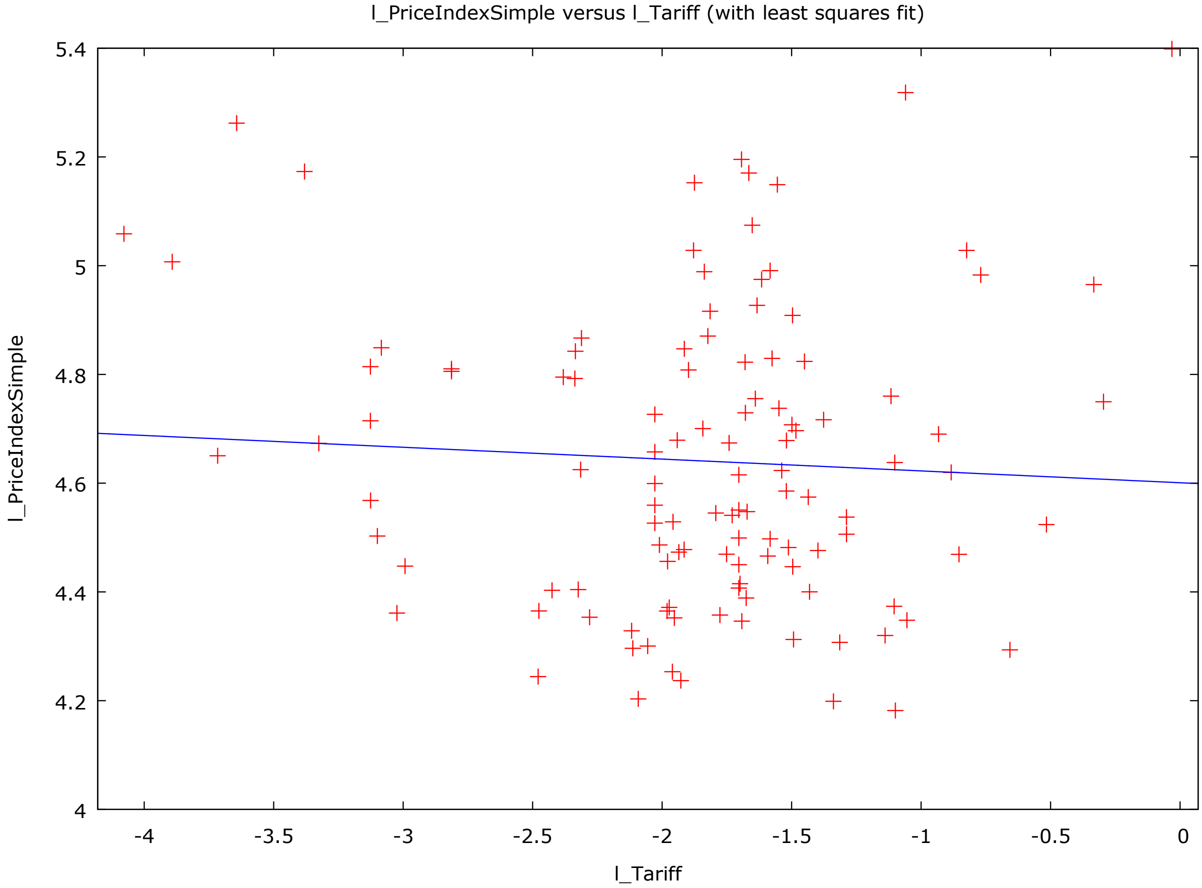

Figure 1: Relationship between tariff rate and prices

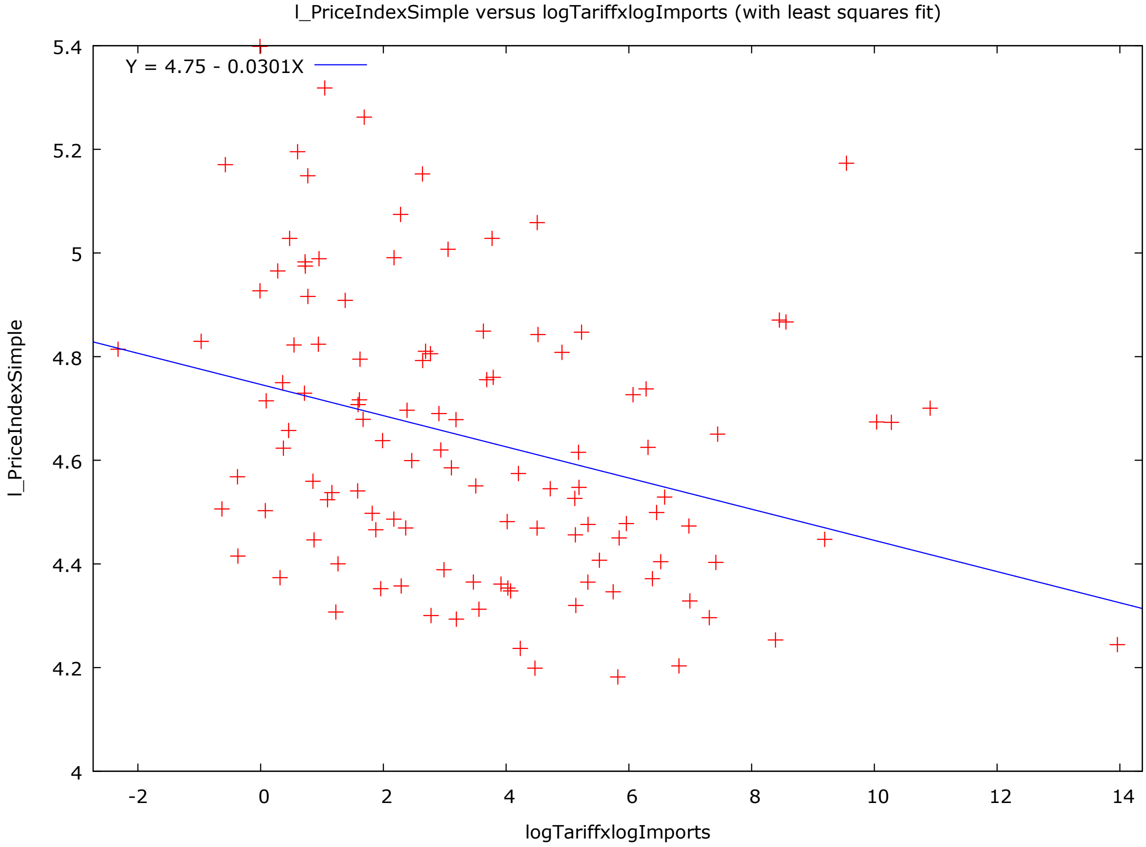

Figure 2: Relationship between a tariff rate and import dependency interaction variable and prices

There was suspected simultaneity bias between prices, and tariffs and imports. Price changes may cause changes in the price competitiveness of imports (and thus the quantity imported). Price changes may also affect the value of specific tariffs when calculated as a tariff rate (i.e. as a proportion of the value of goods) and tariff policy (which also affects tariff rates).

To test for endogeneity, residuals from the structural equation were, separately, regressed on tariff and the tariff-import interaction variables. [11] Significant coefficients on these variables would imply they explain some variation in prices not explained in the structural equation – i.e. there is a relationship between prices and tariffs and/or imports not captured. The lack of significance of these variables, as show in

Table 3 and *Table 4* provides some evidence that error terms are unconditional of regressors.

[11] Ideally an instrumental variable would be used to test for endogeneity but no such variable was found in the literature. It was also not possible to test by estimating adding residuals from reduced form equations of tariffs and the tariff-import interaction to the structural equation due to exact collinearity

Table 3: Endogeneity test - Dependent Variable: Residuals from structural equation; n=115; Heteroskedasticity-robust standard errors, variant HC1[12]

$lnMFNTariffRate$	0.00
	(0.02)~
$Constant$	0.00
	(0.03)~
R-Squared	0.00

Table 4: Endogeneity test - Dependent Variable: Residuals from structural equation; n=115; Heteroskedasticity-robust standard errors, variant HC1

$lnMFNTariffRate \times ImportDependency$	0.00
	(0.01)~
$Constant$	0.00
	(0.02)~
R-Squared	**0.00**

<u>Adjusting Functional Form</u>

GDP per capita is included as a cubic function and labour as a squared function – both display these properties graphically as show in

[12] ~ indicates not significant at the 5% significance level

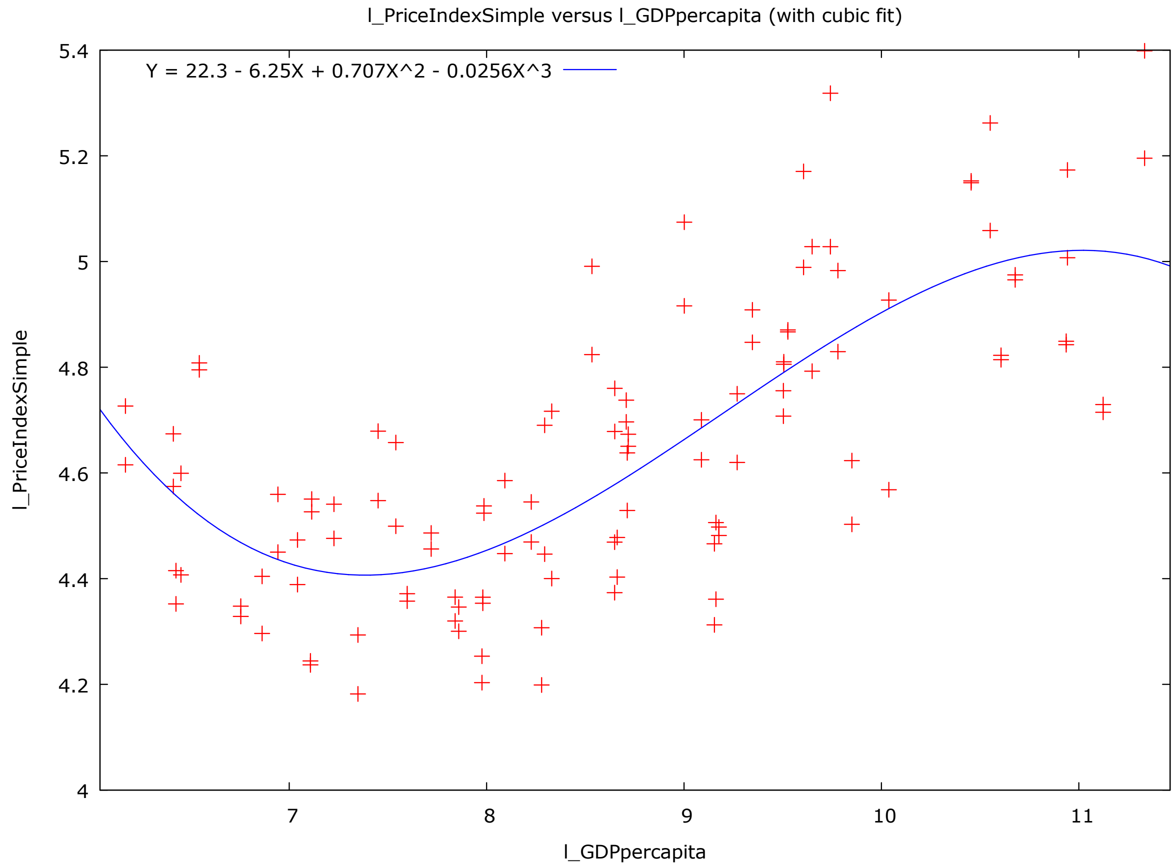
l_PriceIndexSimple versus l_GDPpercapita (with cubic fit)
Y = 22.3 - 6.25X + 0.707X^2 - 0.0256X^3
l_PriceIndexSimple
l_GDPpercapita
5.4
5.2
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Figure 3 and

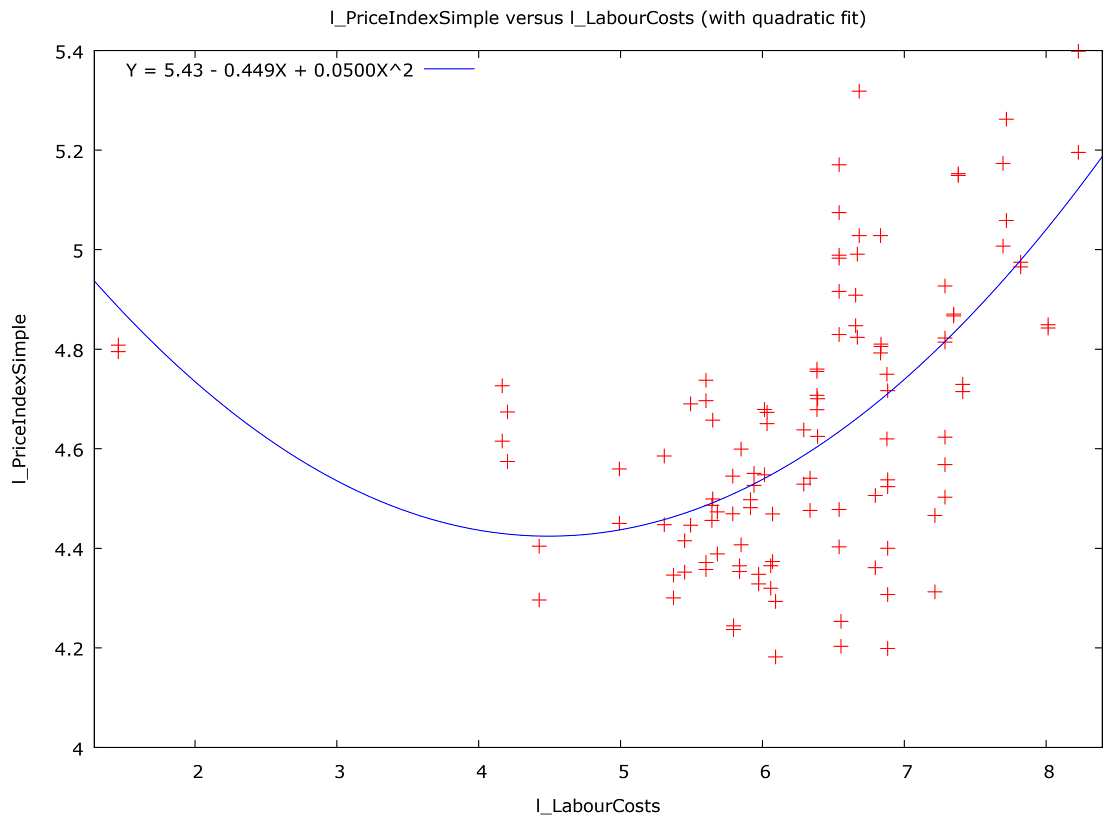
l_PriceIndexSimple versus l_LabourCosts (with quadratic fit)
Y = 5.43 - 0.449X + 0.0500X^2
l_PriceIndexSimple
l_LabourCosts
5.4
5.2
5
4.8
4.6
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Figure 4. This influenced these choices along with non-linearity tests on different functional forms.

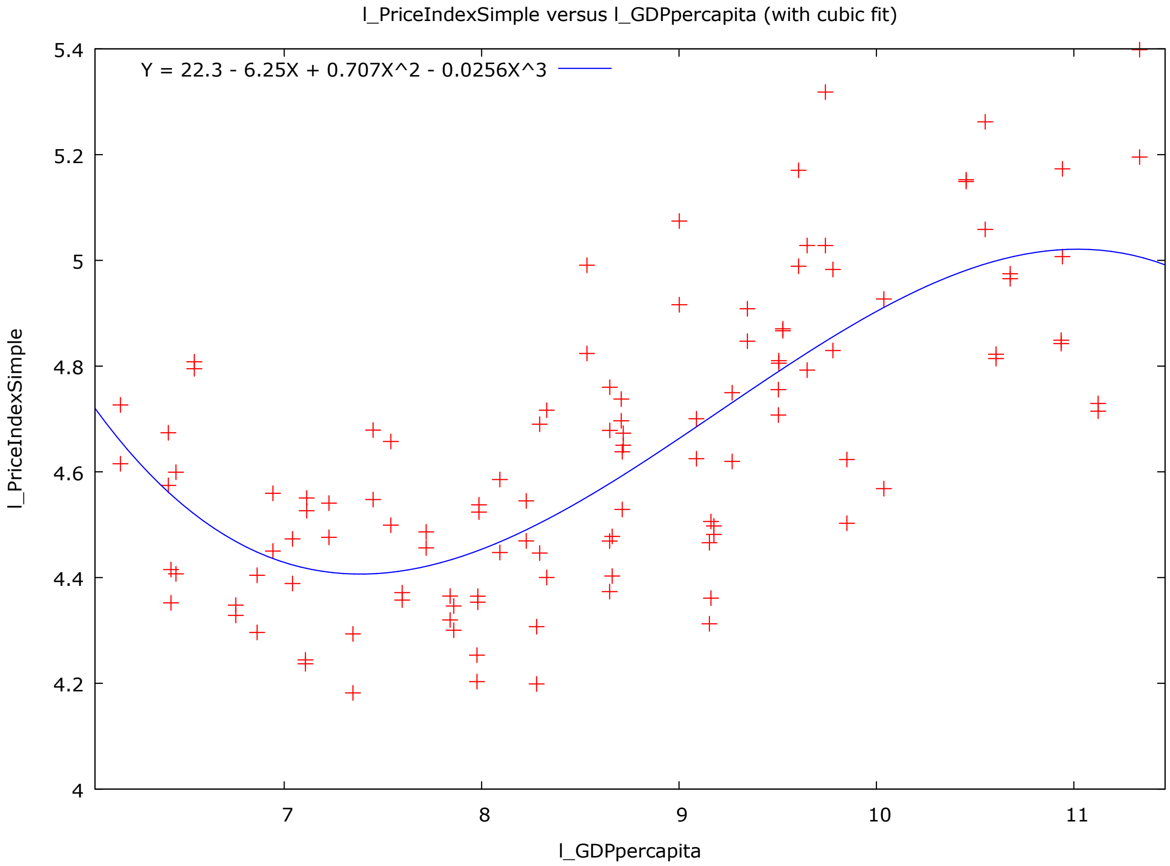

Figure 3: GDP/capita and Agri-Food Prices

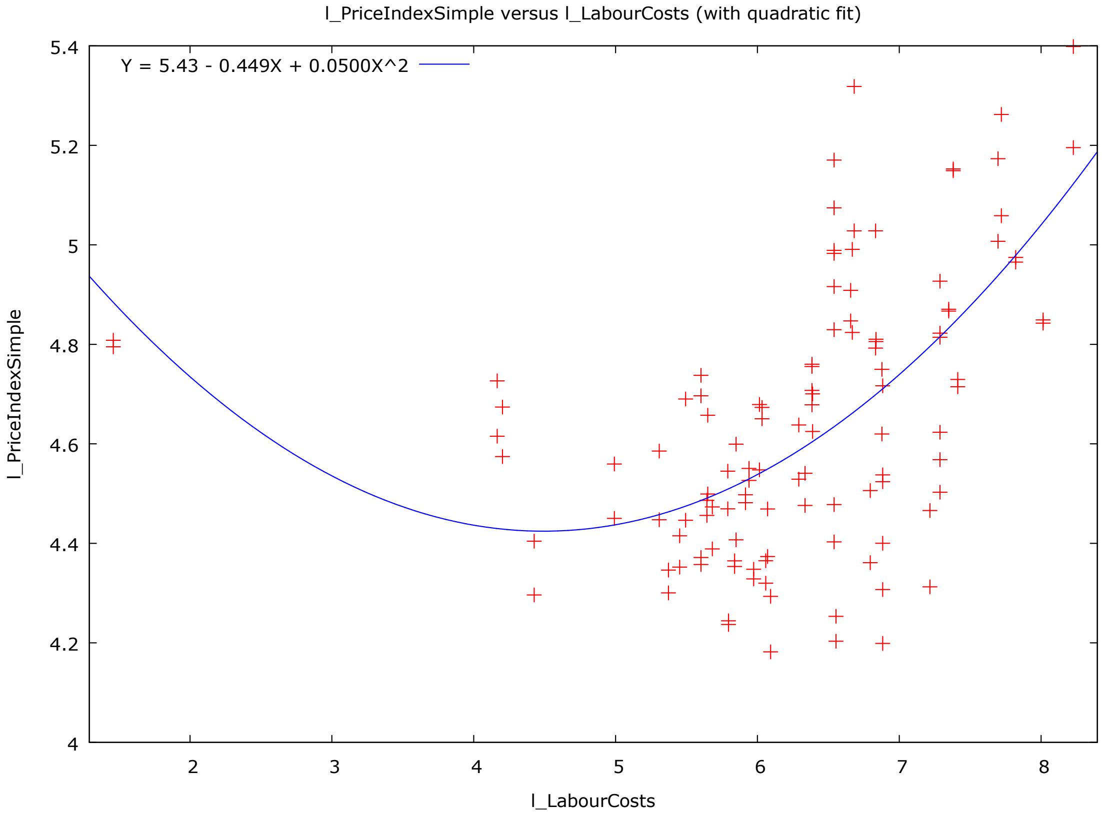

Figure 4: Labour Costs and Agri-Food Products

<u>Measurement Error</u>

Generally, econometric models estimated during this research were homoscedastic; had error terms that are normally distributed and satisfied the zero conditional mean of error assumption. However, while estimated coefficients are largely consistent in direction and magnitude, their significance varied. This suggests the OLS estimation presented in this paper may not be unbiased. Measurement issues could be a reason for this. The Most Favoured Nation (MFN) tariff rate may be correlated with the measurement error (the difference between MFN and effective tariff rates). This could be because countries conducting more free trade deals may have lower effective tariff rates relative to their MFN rate to give themselves greater negotiating capital.– This would increase the measurement error for these countries. This could bias the OLS estimation of coefficients such that they are less significant (Wooldridge, 2016).

As data limitations prevents correction of measurement error issues, the existence of relationships between prices and some variables (including those excluded from the estimation) may be more likely to exist then suggested by student t-tests reported in the *next subsection*. Results are generated to provide a *proof of concept* of the methodology for estimating NTMs and exploring their effects on food security in a computable general equilibrium (CGE) model.

Results

A weak, negative relationship was provisionally estimated between the frequency index of Sanitary and Phytosanitary (SPS) measures and the prices of 'animal-related agri-food products' and 'food products' product groups. *Table 5* shows a $one\ percent$ increase in the proportion of products within a product group that is covered by at least one SPS measure could decrease prices of that product group by around 0.06%.

Table 5: OLS estimation. Dependent variable: lnAgriFoodPrices (simply weighted); heteroskedasticity-robust standard errors, variant HC1

$lnSPSFrequencyRatio$	**-0.055**
	(0.02)***
$lnSPSFrequencyRatio \times DevelopmentRanking$	**−0.099**
	(0.05)**
$lnMFNTariffRate$	**0.010**
	(0.02)
$lnTariffRate \times lnImportDependency$	**−0.008**
	(0.01)
$lnGDPpercapita^3$	**−0.014**
	(0.01)**
$lnGDPpercapita^2$	**0.374**
	(0.15)**
$lnGDPpercapita$	**−3.121**
	(1.37)**
$TransportCosts$	**0.005**
	(0.00)***
$lnLabourCosts^2$	**0.010**
	(0.01)
$lnLabourCosts$	**−0.148**
	(0.05)***
$AnimalDummy$	**−0.022**
	(0.03)
$Constant$	**12.969**
	(4.09)***
Observations	**155**
F-stat (11,103)	**46.90**
F-test p-value	$\mathbf{4.25e^{-35}}$
Adjusted R-squared	**0.751**

*Where '**' is significant at the 5% significance level and '***' is significant at the 1% significance level*

Given the *frequency-based* nature of data construction, the effect of more burdensome NTMs on prices cannot be inferred. However, the estimation provisionally suggests SPS measures have a negative price effect. A reason for this could be that a greater number of SPS measures may increase consumers' trust in imported goods. This increases demand for imports. Assuming imports are cheaper than domestically produced goods (because countries export goods they have a comparative advantage in producing), this will reduce domestic market prices. However, this assumes the typical consumer is both are aware of, and has trust in, these technical measures imposed on food imports to keep them safe. Some may argue consumers in more institutionally developed countries may, *indeed*, trust their governments' regulations. Although, this reasoning would require consumers to be aware of *changes* in SPS measures (to become even more trusting of imported products). Public economics suggests that if the market failed to signal that imports had improved in quality, the changes in SPS measures would have to be accompanied by government intervention. This could be via an information campaign or product labelling.

It is vital to note the empirical estimation does not attempt to prove this theory. Further work using other dependent variables, such as the quantity of imports would need to be conducted to test for causality. This practically demonstrates Jager & Lanjouw's (1977) argument that it is the relationship between NTMs and imports rather than prices that matters.

The table also shows that the relationship between SPS measures and prices is stronger for more developed countries – this is also found by others (see Cadot & Gourdon (2014) and World Bank (2018)). For example, if Ethiopia and Australia (which have a similar number of SPS measures on their 'food products') both increased their SPS frequency ratios by $5\,percentage\,points$, the marginal effect on prices would differ According to the results above, this change in SPS measures could cause food products prices in Ethiopia (which has 'low' human development) to fall by 0.22% whereas prices in Australia (which has 'very high' human development) to fall by more (0.30%).[13] This aligns with the reasoning above because consumers in countries with higher development may have greater trust that their governments' regulations will increase standards. They may also have stronger preferences towards goods perceived to be of a higher standard. Thus, when standards of imported goods increase, they will import more at the margin relative to consumers in lower income countries.

5. Methodology II: Non-Tariff Measures and Food Security

Methodology and Results I presented a weak, negative relationship between the frequency index of Sanitary and Phytosanitary (SPS) and domestic market prices of 'animal-related' agri-food products and (semi-)processed 'food products'. To investigate the effect of changes to SPS measures on food security, this relationship is incorporated into the Global Trade Analysis Project (GTAP) framework computable general equilibrium (CGE) model. This model is described in the *first subsection*. The rest of *this chapter* describes the modification to the model to consider changes in the frequency index of SPS measures and the experiment designed to demonstrate this modification.

[13] Human development classifications are given in (UN Development Programme, n.d.)

CGE Model[14]

Figure 5 shows the CGE model is 'general' as considers the entire world economy. The world is split into 141 regions (i.e. countries) which are divided into 65 'GTAP sectors' (e.g. industries such as 'red meat').[15] The sectors can buy and sell goods they produce to both domestic and foreign: households, governments and other sectors. Households, modelled as a representative household for each region, sell factors of production to domestic firms (i.e. GTAP sectors).

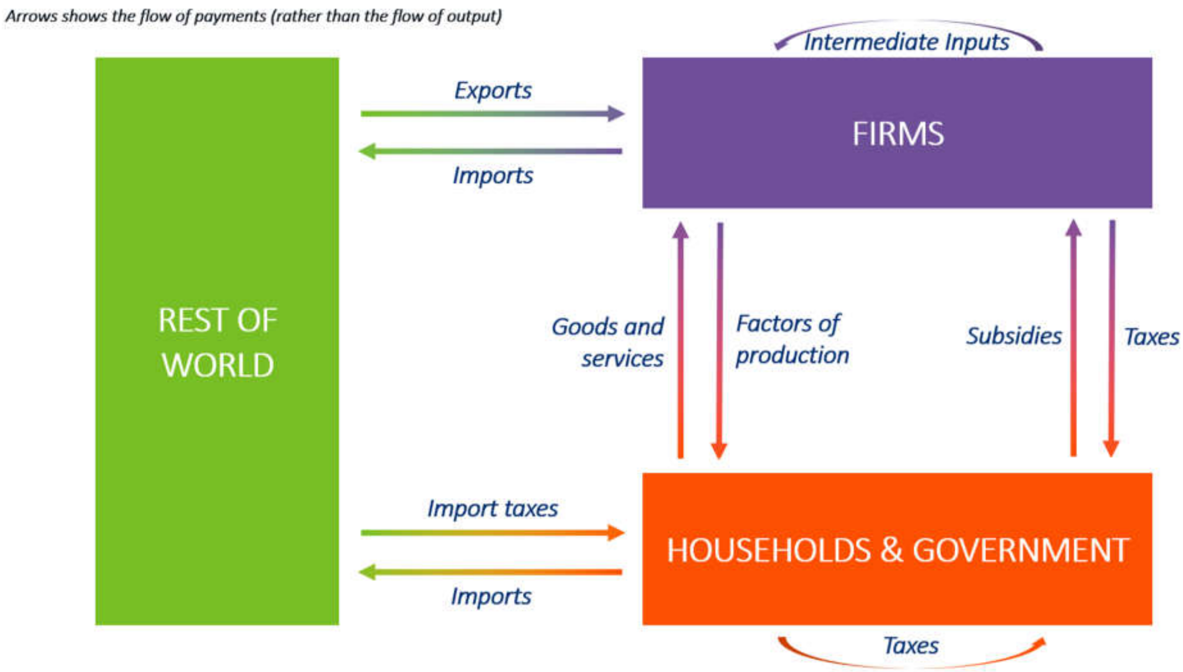

Figure 5: Simplified diagram of the GTAP framework computable general equilibrium model

The model solves in 'equilibrium' as everything that is produced by firms is consumed by other economic agents (i.e. demand equals supply). Also, all factors of production are fully employed. Prices of goods and factors adjust to ensure this occurs.

The comparative static nature of the model means the global economy is simulated to move from an equilibrium, in an initial period, to another equilibrium, in a subsequent period, without specifying a timeframe for these equilibria.[16] This mechanism means it is not possible to analyse the transition to new equilibriums – structural change can be costly to economic agents, thus gains to societal welfare can be overstated in the model.

The model structure is largely made up of linearised, simultaneous behavioural equations determining perfectly competitive relationships between economic agents. Firms are modelled as price takers so prices are determined by changes in demand as well as input prices. Factor

[14] See Corong et al. (2017) for a fuller description of the model which is used to inform *this subsection*. Note, this is also the citation for the model itself

[15] See *Appendix A* for mapping of GTAP sectors to NTM product groups and *Appendix B* for the regional and sectoral aggregation

[16] However, given the value of parameters, outputs from the model are commonly interpreted as occurring over the long-run after shocks occur.

prices are thus determined by changes in firms' demand as well as regions' relative endowments of these factors.[17] In reality, some producers and consumers exhibit market power which make prices stickier, thus changes in quantities can be underestimated by the model.

When the model is shocked, changes in relative prices, within behavioural equations, interact with pre-determined behavioural parameters (such as elasticities) to drive changes in production, consumption, and trade. Changes in domestic prices relative to foreign prices cause changes in the price competitiveness of exports. This affects trade flows. Trade parameters are based on the Armington assumption. This assumes heterogeneity of goods based on where they are produced (e.g. it assumes British red meat is different to Australian red meat). Therefore, consumers consume the same good from both a variety of foreign sources as well as domestic producers.

There is large uncertainty regarding the true value of Armington elasticities. This means economic agents could be significantly more or less sensitive to changes in results than suggested in *Results II*. So, focus should be paid to the direction rather than the magnitude of findings in that chapter.

The model's database is from 2014 so outputs represent changes from shocks relative to the world in 2014.

SPS Modification

The description of the CGE model above implies modifying the model should be done in two steps. *Step one*, a theoretical extension must be designed which is compatible with the existing perfect competition economic mechanism. *Step two*, this theoretical extension must be expressed as linear behavioural equations made up of variables and coefficients (including parameters).

This reveals a trade-off between *accuracy*, ensuring that the modification is as representative of the empirical behaviour the modeller is trying to incorporate, and, *modelling practicability*, ensuring the modification is possible within the software and is consistent with the theoretical mechanisms of the rest of the model.

SPS Modification - **Step One:** Devising a Theoretical Modification

As discussed in *Method I*, the negative relationship between the frequency index of Sanitary and Phytosanitary (SPS) measures and prices could be due to consumers' trust of imported goods. So, as *step one*, a theoretical extension is proposed where a reduction in the proportion of SPS measures imposed on a product group reduces consumers' trust in those imported goods. This makes imports less desirable which is represented by an increase in their prices.

This modification assumes the empirical relationship estimated earlier was based on import prices faced by households. However, it is likely that the price level indices (PLIs) used were

[17] The model's database does not include prices. Instead, prices are all relative to a numeraire, a largely unused variable set equal to one

composite prices faced by households.[18] Therefore, the estimated coefficient is likely to be an underestimate of the relationship between prices and changes in SPS frequency index. This is because while there is a clear theoretical link between SPS measures and import prices, there is no such link between SPS measures and composite prices – particularly without including changes in the quantity of imports as an intermediary. Thus, empirical estimation of the association between changes in SPS measures and composite prices will be weaker than estimation of the association between SPS measures and import prices. Hence, using composite prices as a proxy for import prices likely underestimates the price-effect of changes in SPS measures.

It would not be appropriate to put the estimated coefficient in the CGE model via the equation that determines composite household prices. Firstly, this is because of the lack of economic reasoning directly linking the incidence of NTMs to composite prices. Secondly, placing the empirically estimated price-effect within the equation determining composite prices would not affect the price wedge between domestic and imported goods. Thus, changes in the NTM frequency index would affect prices but not trade, this is unacceptable as the effect on trade is the primary purpose of the modification. Thirdly, given the constraints of linear modelling within the TABLO language, it was not possible to condition the relationship on countries' HDI ranking (as in the empirical estimation) without introducing disproportionate complexity.

This demonstrates the trade-off between *accuracy* and *modelling practicability*. With this modification to the model, a rough sense of the magnitude of, and the participants in, the relationship is retained. However, the empirical estimation is imperfectly represented so the modification can complement existing behavioural equations within the model.

SPS Modification - **Step Two:** Implementing the Modification

To express this empirical relationship within the model, the price effect of a change in the frequency index of SPS measures, (as calculated in *Equation 2*), is incorporated in the equation determining import prices of goods faced by households.

Equation 2: Price effect of a change in the frequency index of SPS measures

$$\boldsymbol{Price\ effect\ of\ changes\ in\ SPS\ frequency\ index = (Change\ in\ SPS\ frequency\ index^{coefficient} - 1) * 100}$$

To do this, *SPSFREQ,* a term determining the change in the frequency index of SPS measures, is introduced. Rules within the TABLO programming language prevented this from being introduced as a variable. This puts a burden on the modeller to ensure their simulations make sense as this set-up makes it possible to increase SPS frequency index beyond 100.[19]

[18] Inferred from ICP methodology (World Bank, 2020)
[19] Furthermore, the SPSFREQ must equal 1 when no change is being simulated to ensure PSPSFREQ equals 0 in these situations.

PSPSFREQ then transforms this change in the incidence of SPS measures into a price-changing effect by utilising a new parameter, *ESPSFREQ* - the empirically estimated price-effect of SPS measures.[20]

For *PSPSFREQ* to be incorporated into the equation determining the price of an imported good, *ppm*, TABLO conventions force *PSPSFREQ* to be multiplied by one.[21]

Figure 6 presents this modification to the CGE model as coded.[22]

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[20] For future developments, where the price-effect of SPS measures is estimated on other goods, *ESPSFREQ* will need to also be indexed over the set of commodities.
[21] This is done via exogenous dummy variable *spsdummy*
[22] Full description of ESPSFREQ in code is: *region-specific elast. between SPS frequency index and price of imported commodities purchased by private households in r*

```
                         ! ----------------------------------
                         TEALE SPS FREQUENCY INDEX EXTENSION
                         -----------------------------------!

! Sanitary and Phytosanitary (SPS) measures frequency index extension !

Coefficient (parameter)(all,i,TRAD_COMM)(all,r,REG)
    SPSFREQ(i,r)
    # change in frequency index of SPS measures on imported com. c. default = 1 #;
Read
    SPSFREQ from file GTAPPARM header "SPSF";

Coefficient (parameter)(all,r,REG)
    ESPSFREQ(r)
    # region-specific elast. between SPS frequency index and price of imported com
Read
    ESPSFREQ from file GTAPPARM header "SPSE";

Coefficient (all,i,TRAD_COMM)(all,r,REG)
    PSPSFREQ(i,r) # Price effect (as perc. change) of change in SPS freq index #;
Formula (all,i,TRAD_COMM)(all,r,REG)
    PSPSFREQ(i,r) = ((SPSFREQ(i,r)^ESPSFREQ(r)) - 1) * 100 ;

Variable (all,i,TRAD_COMM)(all,r,REG)
    spsdummy(i,r) # shock to one #;

! End of Sanitary and Phytosanitary (SPS) measures extension !

! Modified private household consumption price equation !

Equation PHHIPRICES
# eq'n links domestic market and private consumption prices (HT 21) #
(all,i,TRAD_COMM)(all,r,REG)
    ppm(i,r) = atpm(i,r) + pim(i,r) + PSPSFREQ(i,r) * spsdummy(i,r);

! Original private household consumption price equation

Equation PHHIPRICES
# eq'n links domestic market and private consumption prices (HT 21) #
(all,i,TRAD_COMM)(all,r,REG)
    ppm(i,r) = atpm(i,r) + pim(i,r); !
```

Figure 6: Modification to the standard GTAP v6.2 model incorporating changes in the frequency index of Sanitary and Phytosanitary (SPS) measures

So, when *SPSFREQ* is shocked to decrease, there is an increase in the price of imported goods, *ppm*. *Figure* 7 shows this reduces the price of domestically produced goods, *pp*, relative to imported goods. This in turn reduces aggregate imports, *qpm*.

```
Equation PHHLDAGRIMP
# private consumption demand for aggregate imports (HT 49) #
(all,i,TRAD_COMM)(all,s,REG)
    qpm(i,s) = qp(i,s) + ESUBD(i) * [pp(i,s) - ppm(i,s)];
```

Figure 7: (Unchanged) equation for aggregate import in the standard GTAP model v6.2

Trade Liberalisation Experiment

An experiment simulating a free trade agreement is used to demonstrate the modifications to the CGE model. This is because liberalisation of NTMs usually occur with tariff liberalisation as part of free trade agreements.

A 25-region aggregation is used where each region as unique relationships with other regions.[23]

An 11-sector aggregation was chosen to correspond to WITS agri-food product groups and enable analysis of distinct food groups. However, the mapping between aggregated GTAP sectors and WITS product groups does not match exactly.[24] This means *ESPSFREQ* may not accurately reflect the price effect for the products its applied to in the CGE model.

The experiment compromises of two scenarios:

1. **Full Tariff Liberalisation (FTL):** All tariffs within the trade bloc are removed
2. **Full Tariff Liberalisation + 50% SPS Liberalisation (T&SL)**: FTL plus 50% liberalisation of regions' SPS frequency index ratio (within the trade bloc).

The "trade bloc" incorporated all regions in the aggregation apart from the 'EU' and 'RoW' (rest of the world) regions. [25]

"SPS liberalisation" was applied to all sectors in the model to prevent unwanted general equilibrium effects from non-tariff measure (NTM) liberalisation of just agri-food sectors. In trade agreements all sectors tend to have some degree of NTM liberalisation applied to them. However, this assumption assumes the same weak, negative relationship between NTMs and prices as between SPS and agri-food goods. This is likely to be an unrealistic assumption. The trust-increasing effect of NTMs is likely to be unique to food. Therefore, the analysis in the *following chapter* may misestimate the marginal impacts of SPS liberalisation on food security. Although it is clear SPS liberalisation makes imports less price competitive, the complex general equilibrium effects make it difficult to say in which direction this misestimation will occur (given the many factors determining food security).

The analysis in the *next chapter* will focus on the 'marginal impact of SPS liberalisation' – i.e. outputs of the *T&SL scenario* relative to the *FTL scenario* (i.e. $Marginal\ impact = T\&SL - FTL$).

[23] See *Appendix B* for full regional and sectoral aggregation
[24] For example, fish and eggs are in the WITS animal agri-food product group but not in the animal agri-food sector in the CGE model
[25] EU countries are aggregated into one region while all other countries are aggregated into a 'Rest of World' region

6. Results and Discussion II: NTMs and food security

This chapter uses the experiment, described in *Methodology II*, to demonstrate the novel model modification to the computable general equilibrium (CGE), presented in this paper.

Analysis, within this chapter, will focus on the marginal impact of SPS measures on the self-sufficiency and affordability of 'animal-related agri-food goods'.[26] This is because this sector is similar to one of the product groups used for the empirically estimated relationship between SPS measures and prices. Furthermore, as it almost solely compromises of meat and dairy products it has a more practical interpretation for food security.

Self-Sufficiency

For most countries, CGE modelling shows liberalisation of SPS measures across all sectors increases self-sufficiency in meat and dairy products – as shown in

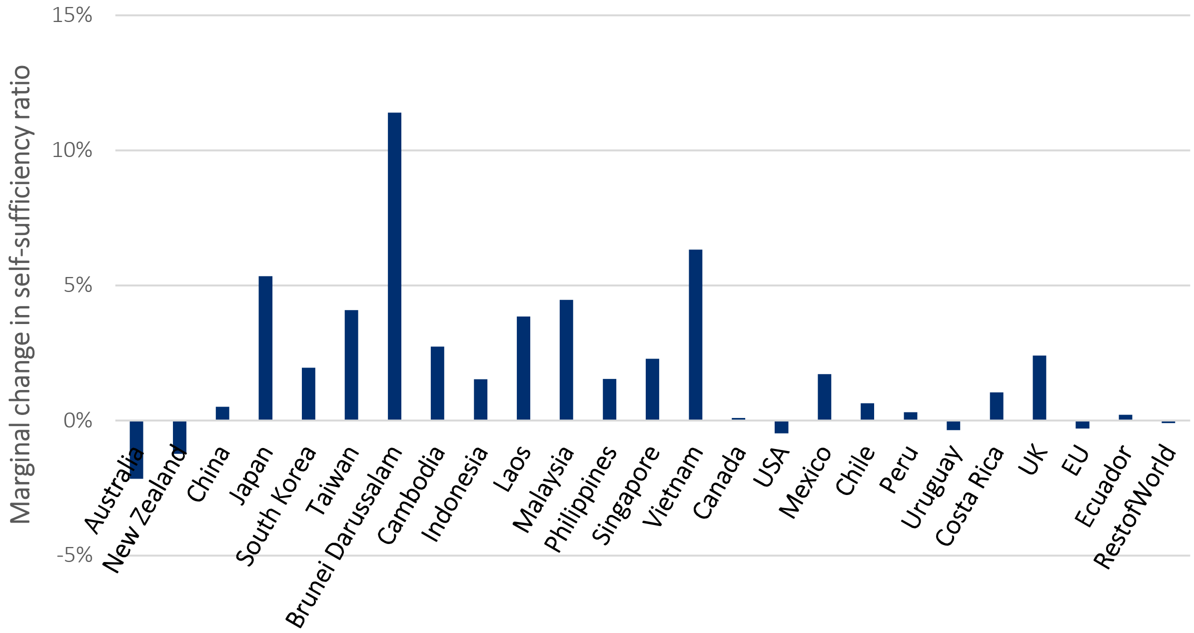


Figure 8.[27] While self-sufficiency does not determine food availability, greater self-sufficiency increases countries' resilience to shocks to the global food market by increasing their ability to satisfy their demand with domestic production.

[26] See *Appendix B* for CGE sectoral aggregation of animal related agri-food products

[27] CGE models are simplified simulations of the world. All point estimates given in this paper should be treated as an indication of potential direction and magnitude of impacts rather than precise estimations

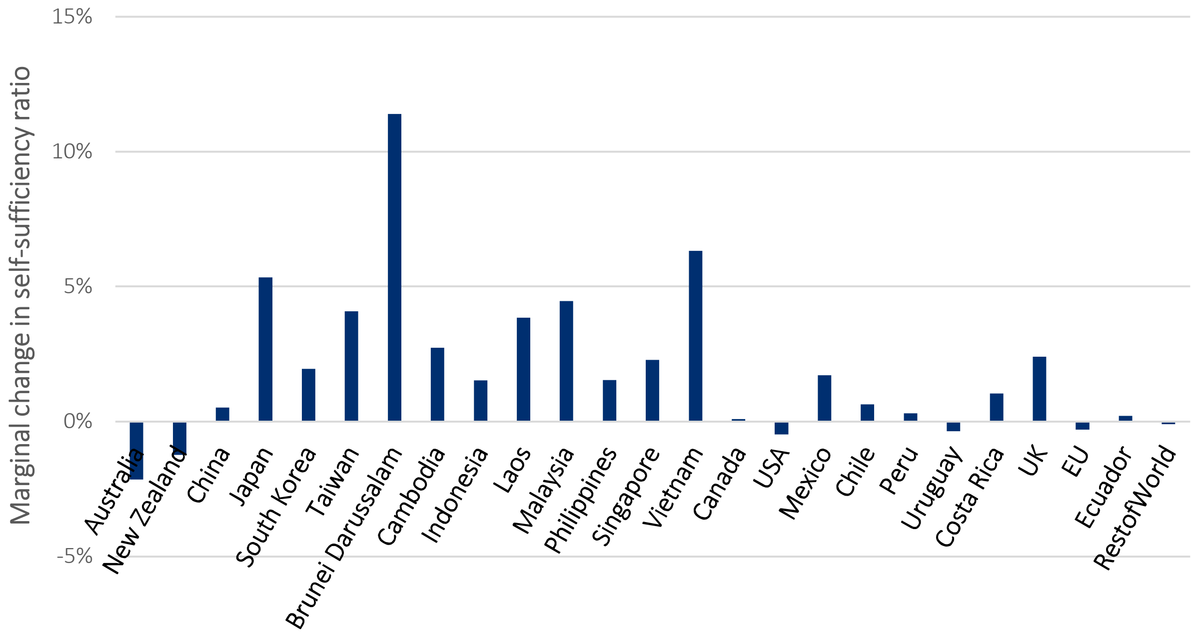


Figure 8: Marginal effect of SPS liberalisation on countries' <u>self-sufficiency</u> of animal-related agri-food goods

Given the estimated weak, negative relationship between SPS measures and import prices, liberalisation of SPS measures makes imports of animal-related agri-food goods less price competitive. In the CGE model, this raises the composite prices of these goods which incentivises greater domestic production and reduces demand (consumption) of meat and dairy products. Greater domestic production relative to consumption improves self-sufficiency.

The deterioration of some countries' self-sufficiency may be because these countries are net exporters of meat and dairy. SPS liberalisation reduces the international price competitiveness of their exports which disincentivises production reducing their self-sufficiency. Evidence of this is shown by *Figure* 9 and

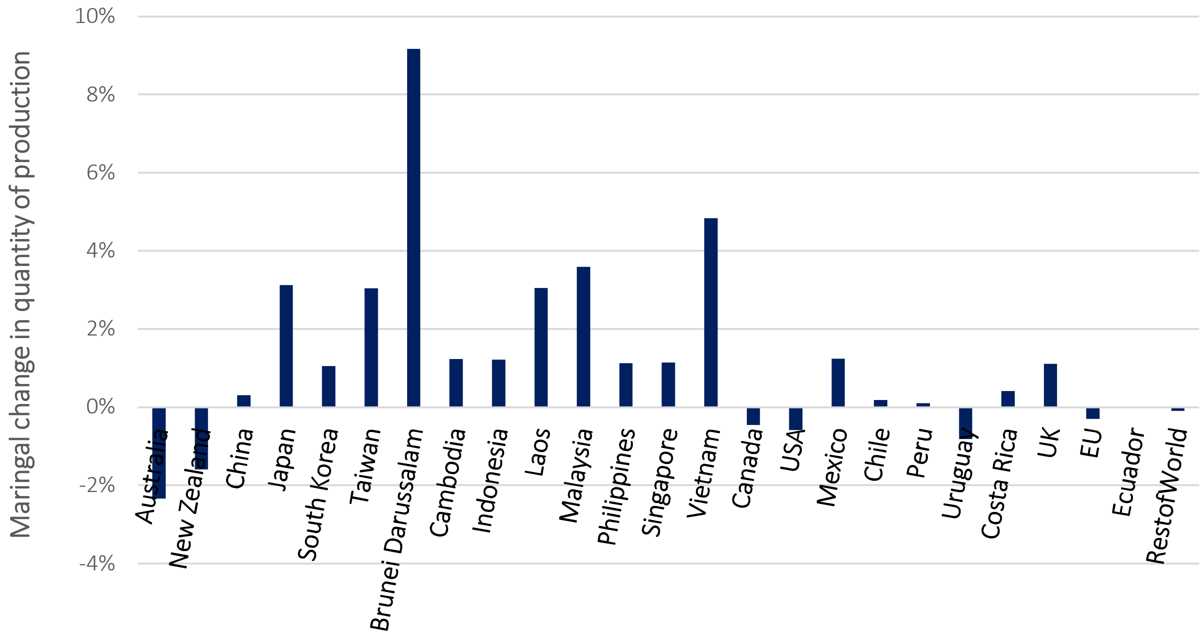


Figure 10. These figures show the countries for which their self-sufficiency deteriorates following SPS liberalisation (Australia, New Zealand, USA, Uruguay and the EU bloc) are the

same countries which see reduced net exports of animal-related agri-food goods and a contraction in production of these goods.

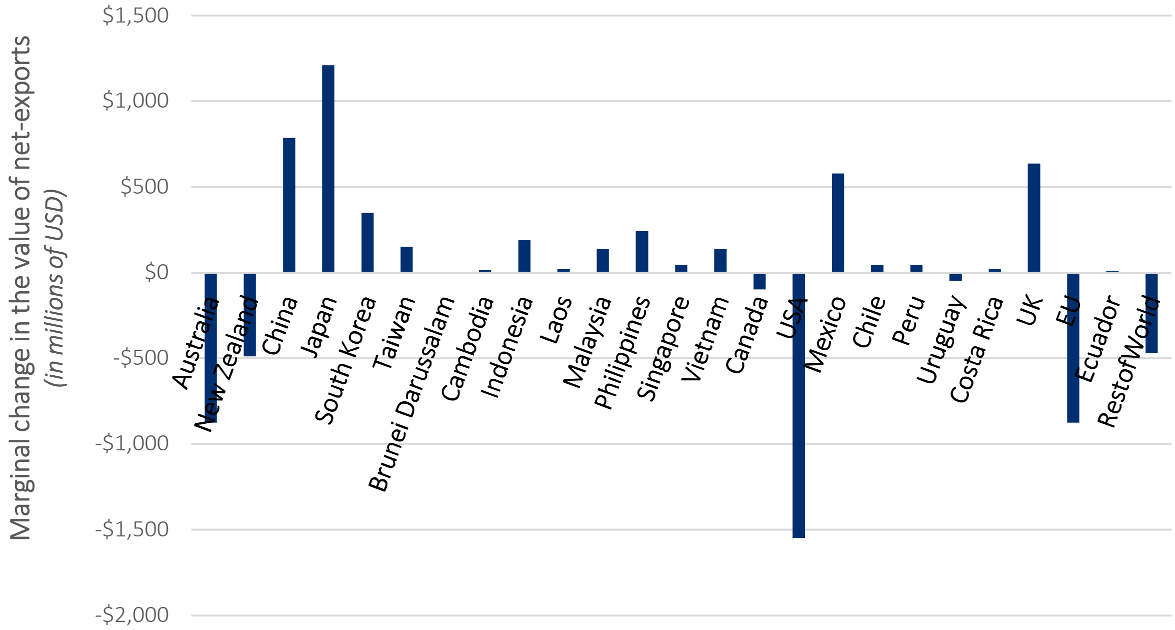


Figure 9: Marginal effect of SPS liberalisation on countries' net exports of animal-related agri-food

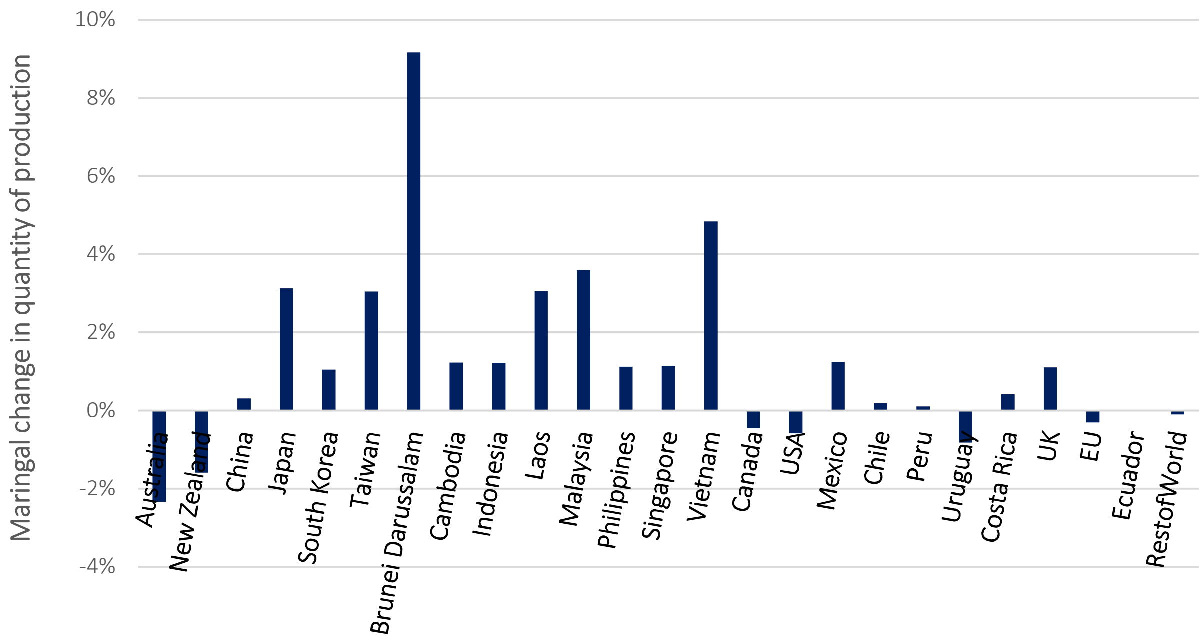


Figure 10: Marginal effect of SPS liberalisation on countries' production of animal-related agri-food

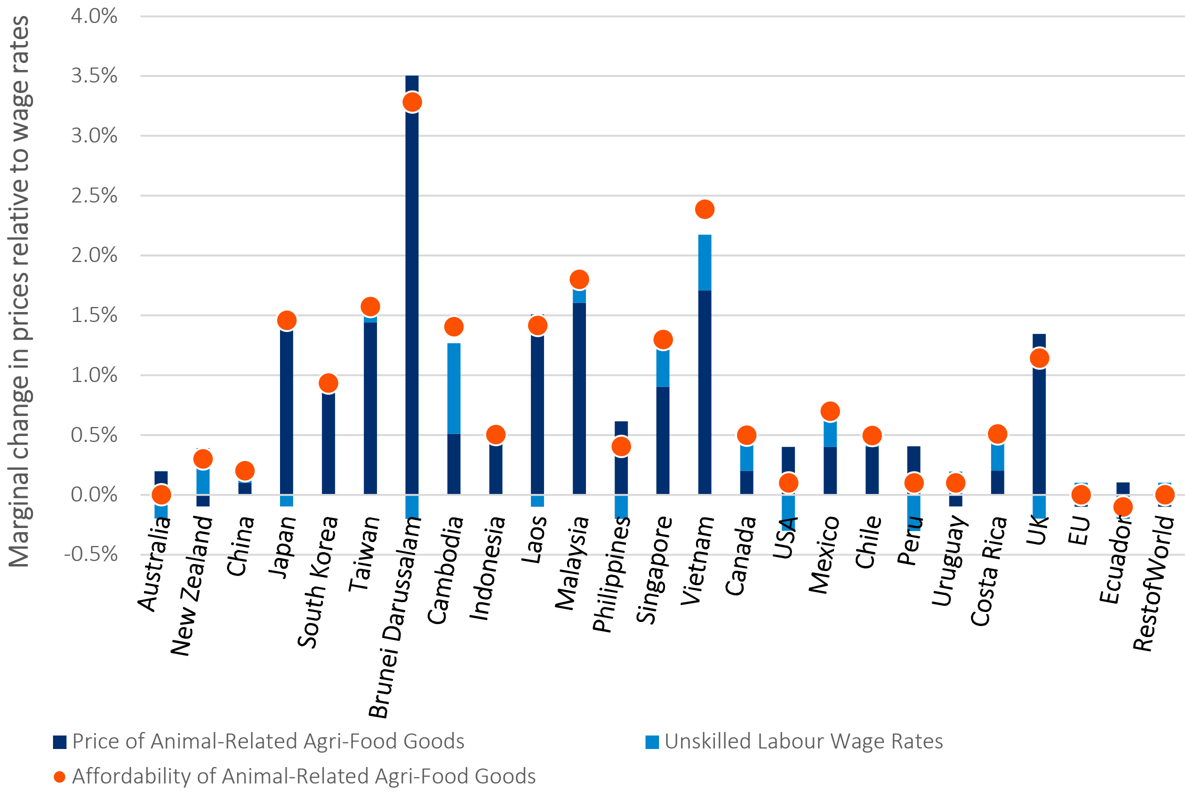
An exception to this is Canada. The model estimates Canada's net exports of meat and dairy fall following SPS liberalisation causing the sector to contract, but it also estimates an improvement in Canada's self-sufficiency. This is because the decrease in consumption of animal-related agri-food goods outweighs the contraction in production – this happened in Canada's case, as shown in *Table 6*. As explained earlier, consumption may fall following SPS liberalisation because domestic prices rise.

Table 6: Marginal impact of SPS liberalisation of <u>Canadian production</u>, <u>consumption</u> and <u>self-sufficiency</u> of animal-related agri-food goods

Production	−0.5%
Consumption	−0.6%
Self-sufficiency	+0.1%

It is important to note while self-sufficiency may improve countries resilience to shocks to the global food market, it increases their resilience to shocks in their domestic food market. As global food markets have more diverse production processes and supply-chains, they are generally less volatile than local markets (Gillson & Fouad, 2015).

<u>Affordability</u>



The orange marks in Figure 11 shows liberalisation of price-reducing non-tariff measures, within a CGE model, reduces the affordability of meat and dairy products for most countries. Affordability is defined in *this paper* as consumer prices relative to wage rates (consumers *ability* to pay for food).

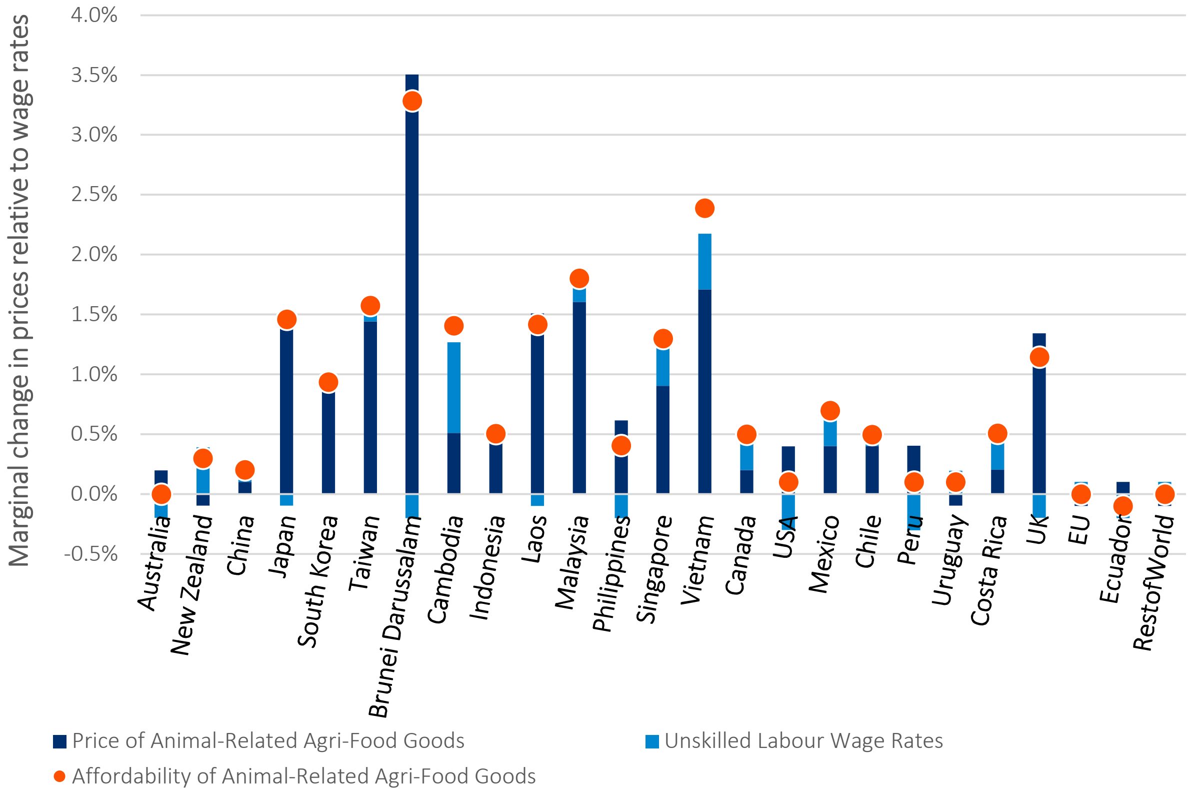


Figure 11 shows affordability deteriorates primarily due to an increase in the price of animal-related agri-food prices (as SPS liberalisation increases prices). Recent literature supports the notion that higher import prices and lower trade can reduce food security (see (Gillson & Fouad, 2015) (Amanta, 2021)).

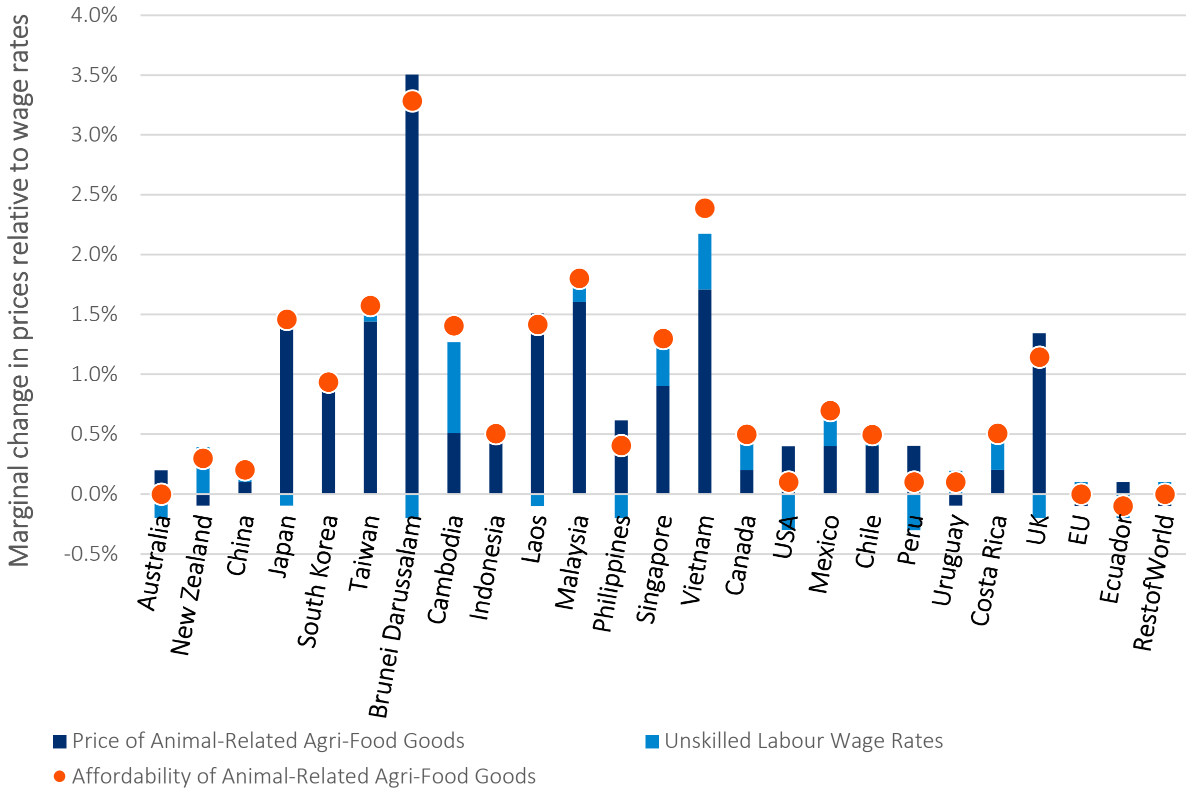


Figure 11: Marginal effect of SPS liberalisation on the affordability of animal-related agri-food goods[28] *The higher up the y-axis, the greater the increase in price (dark blue), the greater the decrease in wage rate (light blue) and the less affordable to goods (orange)*

For most regions in the modelling, liberalisation of SPS measures reduces wage rates (given by rising light blue bars). This is because SPS liberalisation makes foreign produced goods less price competitive in domestic markets. This reduces both imports (typically of goods which regions have a comparative disadvantage in producing) and exports (typically of goods which regions have a comparative advantage in producing). As countries' labour supplies are fixed but perfectly mobile between sectors, labour can shift enabling countries' production to shift towards goods they now import less of. This results in countries producing more goods of which they are less efficient at producing, causing an overall reduction in countries' output, as shown in

[28] Note the stacked bars may not exactly equal the dots due to the nature of using percentage changes in calculations

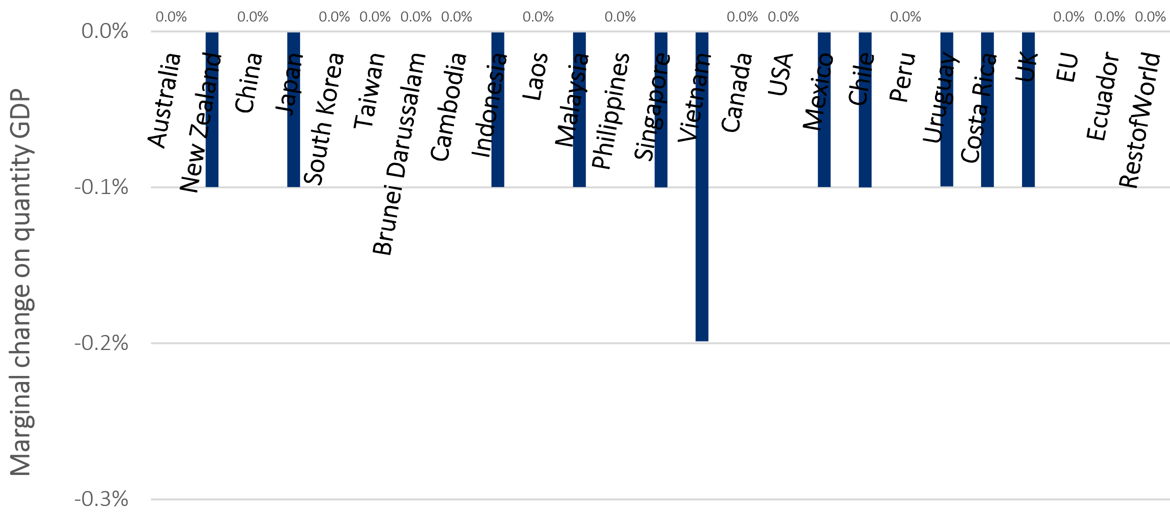


Figure 12. This reduces countries' aggregate demand for labour which reduces wage rates.

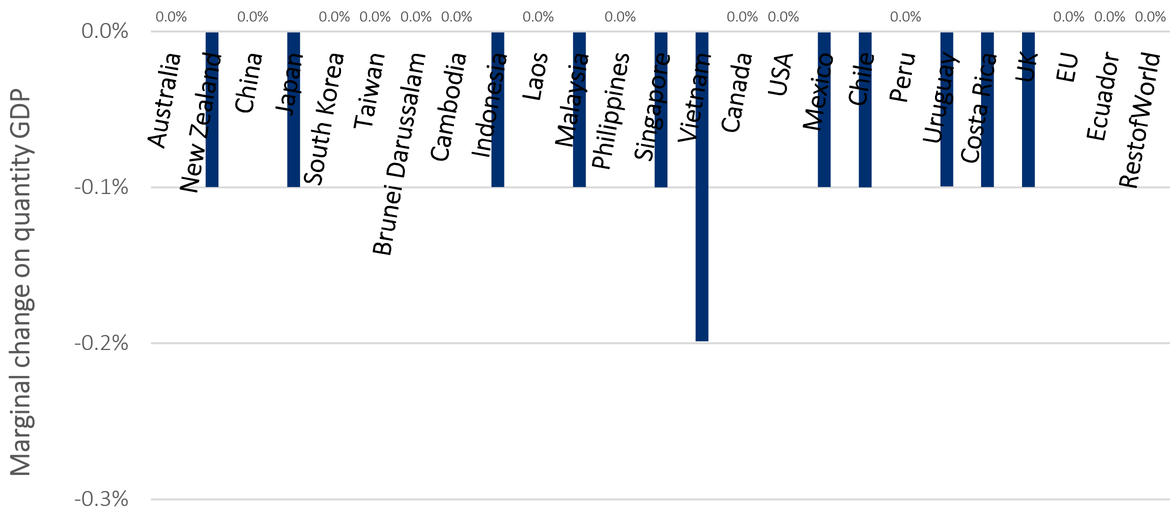


Figure 12: Marginal effect of SPS liberalisation on countries' "quantity GDP"[29]

However,

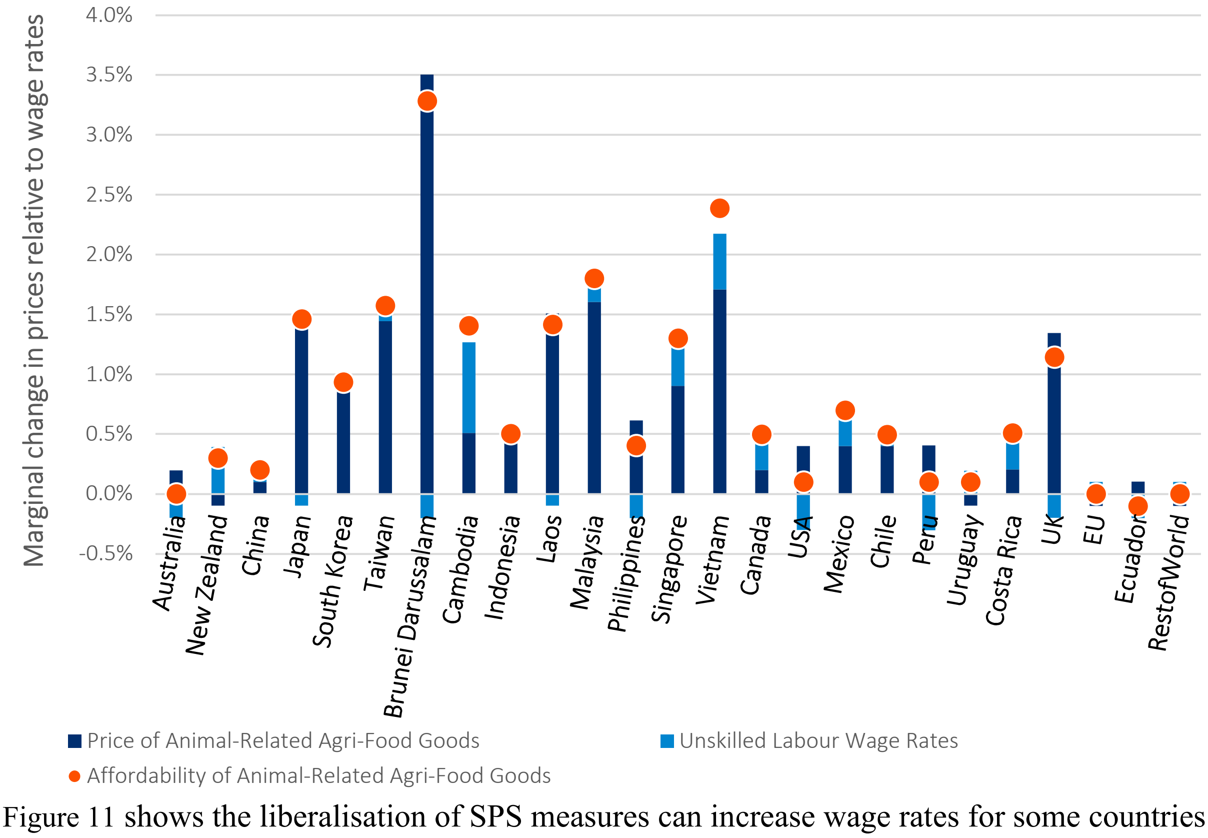


Figure 11 shows the liberalisation of SPS measures can increase wage rates for some countries such as the USA, Ecuador, Australia and Peru (giving by falling light blue bars). This is because, in these regions, SPS liberalisation may cause labour to shift to more labour-intensive sectors. The Heckscher-Ohlin (H-O) model contributes to the theoretical underpinning of the GTAP CGE model. Countries, such as Australia with relatively low endowments of labour (compared to land for example), import labour-intensive goods as they are less efficient at producing them. As the SPS liberalisation shock increases domestic production in goods a

[29] Quantity GDP refers to the volume of goods and services as calculated by the expenditure approach to gross domestic product.
This is reported at 1 d.p. to avoid precision

region typically imports, this shifts labour to sectors that demand more labour to produce a given unit of goods. This increases demand for labour in a country which increases the country's wage rate.

However, *Figure 13* shows that terms of trade may be another factor that influences wage rates when price-reducing SPS measures are liberalised. Terms of trade, the price of a region's exports relative to the price of its imports, is a demand-side factor within the labour market (Anaman, 2003). This is reflected in the GTAP CGE model structure. When terms of trade improve (when exports become relatively more expensive), countries, such as Laos following SPS liberalisation, experience higher wage rates. This is because of the zero-profit, perfect competition set-up of the model links prices of goods to wage rates. Countries' term of trade may have improved because of a decline in global incomes (see the fall in output across all regions in

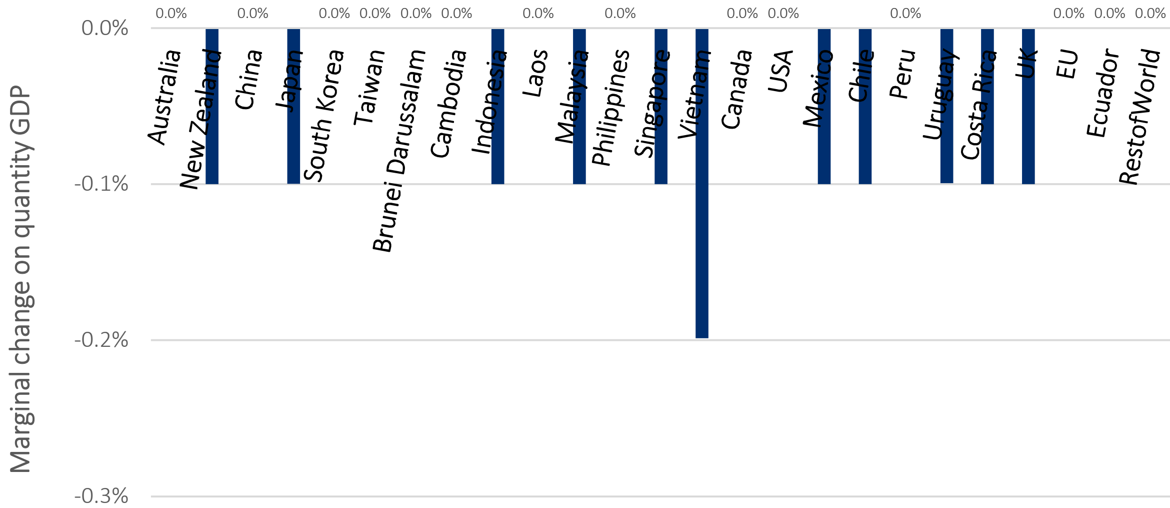


Figure 12) which causes substitution towards necessities. Necessities include vegetable-related agri-food goods – which much of Laos' economy produces, according to the model's database. As demand switches to these goods their price rises. As shown by Laos, this can improve both terms of trade and increase wage rates for countries that net export these goods.

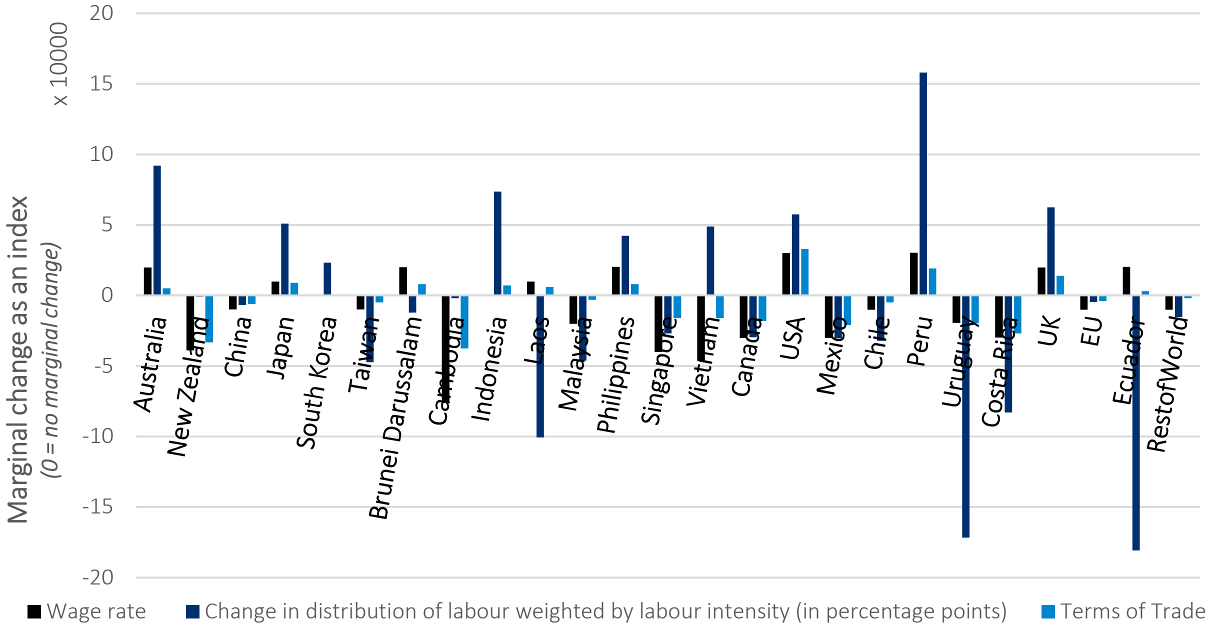


Figure 13: Marginal effect on SPS liberalisation on countries' distribution of labour, wage rates and terms of trade all indexed to a number close to zero[30]

Overall, the liberalisation of price-reducing non-tariff measures, reduces food affordability for most countries. This occurs despite general equilibrium effects of higher prices and changing distributions of labour raising wage rates in some regions. Though, these effects can outweigh increases in agri-food prices – like in Ecuador.

7. Conclusion and Next Steps

This paper investigated novel approaches to analyse non-tariff measures (NTMs). It explored combining empirical estimation with a theoretical, agent-based model. It showed not only that this analytical strategy is viable but enables far-reaching analysis of changes to trade policy grounded in empirical evidence.

Estimation provisionally found a weak, negative relationship between SPS measures and prices of animal-related agri-food goods and processed and miscellaneous food products. Computable general equilibrium (CGE) modelling showed multilaterally liberalising price-reducing non-tariff measures can reduce most countries reliance on foreign producers for food but may reduce the affordability of food for households.

[30] $\boldsymbol{Weighted\ change\ in\ distribution\ of\ labour}_r = \sum_i [\boldsymbol{Labour\ intensity\ in\ database}_{i,r} \times \Delta_{T\&SL-FTL}\boldsymbol{Distribution\ of\ labour}_{i,r}]$

Where: i is sector and r is country and,

$\boldsymbol{Labour\ intensity}_{i,r} = \frac{\boldsymbol{Value\ of\ labour\ input}_{i,r}}{\boldsymbol{Value\ of\ total\ factor\ input}_{i,r}}$, and for each scenario

$$\boldsymbol{Distribution\ of\ labour}_{i,r} = \frac{\boldsymbol{Value\ of\ labour\ input}_{i,r}}{\boldsymbol{Value\ of\ total\ labour\ input}_r}$$

These findings are a by-product of demonstrating the methodological approach so are purely experimental.

Too few observations were used during the econometric estimation. Future research should utilise UNCTAD's researcher file of NTMs in STATA to produce more robust estimation – including of vegetable-related agri-food goods and more types of NTMs.

The general equilibrium modelling was heavily dependent on two strong methodological decisions. The modification of the CGE model relied on changes in the frequency index of SPS measures directly affecting consumer-facing import prices. This is not consistent with the data used to estimate the relationship. Further research should consult trade experts and CGE modellers to improve this. The experiment used to demonstrate modifications to the model assumed a free trade agreement where there was liberalisation of price-reducing NTMs across all industries. It is highly unlikely that non-agri-food sectors face price-reducing NTMs in reality. This could have significant general equilibrium consequences if changed. Future research should run simulations where there is liberalisation of price-raising NTMs of non-agri-food sectors.

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Appendix A

NTM 'Product Groups' (TRAINS dataset via WITS)	**Chapter Level Harmonised System Codes**	**Price 'Items' groups** (ICP dataset)	**Sector in CGE modelling**
Animal Products	HS 01 to HS 05	Meat [1101120] Fish and seafood [1101130] Milk, cheese and eggs [1101140]	Animal-related agri-food Food products Livestock
Vegetable Products	HS 06 to HS 15	Vegetables [1101170] Fruit [1101160] Bread and cereals [1101110] Oils and fats [1101160]	Vegetable-related agri-food Food products & drinks
Food Products	HS 16 to HS 25	Sugar, jam, honey, chocolate and confectionary [1101170] Food products n.e.c. [1101190] Non-alcoholic beverages [1101200] Alcoholic beverages [1102100] Tobacco [1102200]	Food products & drinks

Appendix B

Sectoral aggregation for CGE Modelling:

Sector	**Description**	**GTAP 65 Sector Components**
Animal-related agri-food	*Bovine and other meat products; dairy products*	cmt; omt; mil
Vegetable-related agri-food	*Rice, wheat, grains, fruit and veg; plant-based fibres; crops; vegetable oils and fats*	pdr; wht; gro; v_f; osd; c_b; pfb; ocr; vol; pcr
Food products & drinks	*Sugar; processed food; beverages and tobacco; fish, seafood, potatoes, flour, prepared fruit and veg*	sgr; ofd; b_t
Livestock & products from livestock	*Bovine and other live animals; raw milk; wool and silk*	ctl; oap; rmk; wol
Extraction		
Textiles & clothing		
Light manufacturing		
Heavy manufacturing		
Utilities & construction		
Transport & communication		
Other services		

Regional aggregation for CGE Modelling:

- Canada
- Mexico
- Peru
- Chile
- New Zealand
- Australia
- Brunei
- Singapore
- Malaysia
- Viet Nam
- Japan
- UK
- USA
- China
- Taiwan
- Uruguay
- Costa Rica
- Ecuador
- South Korea
- Laos
- Cambodia
- Indonesia
- Philippines
- EU
- Rest of World