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Pulling back the curtain on 'behind the border' trade costs: The case of EU-US agri-food trade

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Abstract

With the rise of anti-free-trade sentiment on both sides of the Atlantic, there is a growing urgency by trade negotiators to conclude the Trans-Atlantic Trade and Investment Partnership (TTIP) negotiations. The harmonisation of non-tariff restrictions is a key component of the talks, whilst global modelling databases typically lack a price compatible representation of these measures, which lends a degree of bias to *ex-ante* modelling assessments. In the gravity literature, there is (limited) evidence of non-tariff *ad-valorem* equivalent (AVE) estimates of agriculture and food, although disaggregated agri-food activities and/or bilateral EU-US route specific estimates are still in relatively short supply. Using panel data, this study consolidates both of these issues, whilst also proposing an 'indirect' gravity method as a basis upon which to provide econometric non-tariff AVE estimates compatible with the degree of sectoral concordance typically found in global modelling databases. On a general note, the results revealed the presence of significant 'behind the border' trade costs on both sides of the Atlantic, which exceed their tariff counterparts. Using simple aggregated averages, our estimates are comparable with 'direct' gravity method studies. Furthermore, rigorous qualitative and quantitative comparisons on a sector-by-sector basis showed that a number of bilateral non-tariff AVEs are also found to be plausible, although in some cases, with recourse to relevant policy documents and expert opinion, it is debatable whether the EU or the US is more restrictive. Further work could focus on refining the sector specificity of each gravity equation to improve the model's predictive capacity.

Additional keywords: non-tariff trade costs; gravity equation; Trans-Atlantic Trade and Investment Partnership

Abbreviations used: AVE (*Ad Valorem* Equivalent); BRICs (Brazil, Russia, India, China); EP (European Parliament); CEPII (Centre d'Études Prospectives et d'Informations Internationales); HLWG (High Level Working Group); IPR (Intellectual Property Rights); KNO (Kee, Nicita and Olarreaga); NAFTA (North American Free Trade Area); NTM (Non-Tariff Measure); PTA (Preferential Trade Agreement); RTA (Regional Trade Agreement); SPS (Sanitary and Phyto-Sanitary); TBT (Technical Barriers to Trade); TPP (Trans-Pacific Partnership); TTIP (Transatlantic Trade and Investment Partnership).

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Introduction

Over the last two decades, the political and economic landscape has realigned, in large part, due to the steady emergence of the 'BRICs' (Brazil, Russia, India and China) and, more recently, the fallout from the financial crisis which has saddled many western economies with heavy national debts, high unemployment and sluggish growth. From the perspective of international trade, both factors have impacted not only on the *format* of trade promotion, but also on the *nature* of how trade relations are governed between partners. In the former case, there was a time when multilateral and regional trade agreements (RTAs) appeared to act as complements in promoting liberalisation. For example, in the 1990s, as the Uruguay Round was coming to fruition the United States (US) co-signed the North American Free Trade Area (NAFTA) agreement. Similarly, in the early 2000s, China's accession to the World Trade Organisation (WTO) was accompanied by European Union (EU) enlargement. With the exception of the Bali agreement on streamlining trade facilitating customs controls and red tape, the Doha negotiations have largely failed, in large part due to the defensive posture of post-crisis Western governments as well as the newly strengthened developing country lobby with designs on significant improvements on market access (especially in agricultural and food products). In the ensuing period, the US actively pursued strategic 'second best' preferential trade agreements (PTAs), whilst also playing an active role in the on-going Trans-Pacific Partnership negotiations (TPP)[1] . For its part, the EU has forged a similar path.

Turning to the second issue, the rules governing the nature of trade promotion have also evolved. Traditional impediments to trade, such as tariffs, continue on a downward path. In part, this is credited to the effectiveness of the WTO's monitoring and arbitration mechanism, but it is also related to the continued rise of covert 'behind the border' protectionism in the form of industrial policy, export credits or government subsidies; or other not so covert measures such as, for example, health, safety and technical standards; labour and environmental protection laws; treatment of foreign investors; intellectual property rights etc. Typically, it is the developed countries, with more sophisticated institutional capacity, which more vigorously implement the latter form of non-tariff measures (NTMs). Taking a cynical view, even non-covert NTMs may be used as a political tool to deliberately impose a barrier to trade, although it has been pointed out, especially in the domain of agri-food (OECD, 2011), that trade restricting NTMs also pursue legitimate welfare improving objectives such as the lowering of negative externalities (*e.g.*, reduced risk of pest or diseases, improved animal welfare) or even reduced information asymmetry (*e.g.*, food labelling).

In this context, the US has tried to influence the terms upon which RTAs should be negotiated and implemented, by seeking to harmonise said measures with like-minded partners with a view to promoting 'free and fair trade' (The Economist, 2013). In 2011, the seeds were planted for a potential EU-US Transatlantic Trade and Investment Partnership (TTIP) at a High Level Working Group meeting on jobs and growth (HLWG). A significant part of the trade negotiations is dedicated to the establishment of a set of bilateral regulatory integration rules on NTMs relating to sanitary and phyto-sanitary (SPS), technical barriers to trade (TBT) and intellectual property rights (IPR).

In the gravity literature, estimates of EU and US non-tariff *ad valorem* equivalent (AVE) trade costs for aggregate agriculture and food activities are available, both of a bilateral- (ECORYS, 2009; CEPR, 2013; European Parliament ((henceforth EP), 2014) and unilateral (Egger *et al.,* 2015) nature. Moreover, EP (2014) focuses on SPS and TBT measures and provides estimates for an array of disaggregated agricultural and food sectors. More recently, Arita *et al*. (2015) estimate bilateral NTM costs for specific SPS and TBT measures and selected food sectors. As a first aim, this paper seeks to consolidate the literature by providing gravity based EU-US bilateral non-tariff AVE estimates for a broad selection (18) of agri-food sectors.

As an input to the policy making process, respected global modelling databases (*e.g.*, Global Trade Analysis Project - GTAP) suffer from a dearth of non-tariff AVE information, which renders *ex-ante* impact assessments as rather shallow. Therefore, a second aim of this research is to address this shortcoming by proposing an alternative 'indirect gravity' based method as a basis upon which to readily reconcile econometric non-tariff AVE estimates with the more aggregated degree of sectoral concordance typically found in global modelling databases. The study employs a panel dataset, whilst additional statistical tests were implemented to enhance the reliability of our sector-by-sector estimates. Rigorous comparisons with relevant 'direct gravity' based AVE estimates show that the results are highly comparable.

Material and methods

Literature review

The estimation of non-tariff trade costs in the empirical literature either uses 'prices' (domestic and foreign) or 'quantities' (trade flows), while a further sub-classification distinguishes between 'direct' and 'indirect' methods, depending on the respective explicit or implicit treatment of the non-tariff indicators (see Deardorff & Stern, 1998; Ferrantino, 2006, for surveys). A cursory examination of the literature reveals that the quantity based method appears to be the more popular, in large part due to easy access to detailed public databases of trade (Berden & Francois, 2015). Examining the price-approach, Bradford (2003, 2005)

[1]The TPP involves Australia, Brunei, Canada, Chile, Japan, Malaysia, Mexico, New Zealand, Peru, Singapore and Vietnam. Interestingly, China is not party to these negotiations. In a departure from previous US external trade policy, the current US administration unilaterally pulled out of the TPP.

calculates (rather than estimates) the implicit non-tariff impact on prices (indirect method), whilst Dean *et al.* (2009) and Cadot & Gourdon (2014), employ an explicit non-tariff variable (*i.e.*, direct method) to estimate its price rising effect.

Direct methods, in both price and quantity approaches, employ secondary data sources (both quantitative and qualitative) to construct a coverage ratio or dummy variable to indicate the degree of pervasiveness or the presence of a non-tariff restriction within the commodity of interest, which subsequently enters as an explanatory variable in an econometric model (price-dependent or gravity-type quantity-dependent). To this end, data may be taken from inventories of standards and regulations (*e.g.*, UNCTAD TRAINS database); notifications to the WTO on the implementation of new trade regulations or complaints by traders (*e.g.*, WTO World trade Reports). In the context of the EU-US trade relations, EP (2014) use the SPS and TBT notifications to the WTO to build a non-tariff variable that when interacted with the EU-US and US-EU) route dummy, allows for the direct estimation of bilateral AVEs of non-tariff costs. In their study, the sample includes a cross-section (year 2012) of OECD countries. Unfortunately, these methods neglect the relative importance of each measure in restricting trade, while countries which are more transparent appear as more restrictive (Chen & Novy, 2012).

Arita *et al.* (2015) build a non-tariff variable that collects the incidence of SPS type measures between the EU and US in those cases where official concerns have been raised by US and EU exporters. A data sample consisting of three years (2010-2012) and a selection of countries ranging between 20 and 35 (depending on the sector) is constructed to estimate directly the non-tariff impact on bilateral trade. The choice of sectors and the direction for which the AVE is estimated is contingent upon the concern raised (*e.g.*, The EU non-tariff AVE is estimated for red and white meat, maize and soy; whilst non-tariff AVEs for fruits and vegetables are estimated in both directions). In a similar fashion, Winchester *et al.* (2012) narrow the focus to target specific non-tariff costs based on exhaustive databases covering (*inter alia*) TBT and SPS, for specific countries and sectors. A disadvantage of these databases (both global or tailored) is the limited sectorial- and country coverage, whilst the data typically refers to only a single year which precludes the use of a panel database which, from a pure econometric perspective, helps to mitigate endogeneity problems. Another method of data extraction employs questionnaire responses on traders' perceptions of market access. ECORYS (2009) interacts this non-tariff score variable with a route dummy (*i.e.* from EU to US and *vice versa*), which feeds into a standard cross-sectional gravity equation, to estimate bilateral EU-US non-tariff AVEs for agri-food. This approach is potentially open, however, to criticisms of limited sample size and response bias.

Two more direct quantity gap studies merit note. Owing to its sector (HS6 aggregation) and country coverage, Kee *et al.* (henceforth KNO) (2009) is recognised as the most comprehensive source of commodity specific non-tariff AVEs. The authors employ an aggregate import equation to estimate restrictiveness indexes from a dummy variable that accounts for the presence of non-tariff barriers (SPS and TBT) to trade plus domestic support. A second study by Li & Beghin (2012) conducts a meta-analysis (27 papers are considered) of direct quantity gap estimation methods to explain the variation of trade effects of health, safety and sanitary regulations and standards. The study considers differences in non-tariff measurement, data disaggregation and size, different estimation techniques and approaches to deal with zero trade values.

In contrast to the direct approach, which can isolate the trade restrictiveness resulting from specific, or groups of non-tariff restrictions, the *indirect* or implicit approach is better attuned to examining the collective trade restricting impact of all trade barriers which may otherwise be hidden (Dean *et al.,* 2009). Thus, indirect methods start by acknowledging that trade barriers imposed by the importer country cause distortions in trade, reducing import quantities (*i.e.* quantity-gap) and/or increasing import prices (*i.e.* price-gap). Indirect quantity approaches infer the non-tariff impact on trade flows from 'border-effects' (*e.g.* Chevassus-Lozza *et al.*, 2008), 'fixed-effects' (Fontagné *et al.*, 2011), or from the depth of past trade agreements (Egger *et al.*, 2015). As an alternative indirect approach, the 'residual gravity approach' infers the non-tariff impact on trade from the residuals by comparing the value of observed imports constrained by trade barriers, with the expected value of imports in the absence of said trade barriers predicted by the gravity equation (Ferrantino, 2006).

The residual approach has been more extensively applied in services sectors (*e.g.*, Park, 2002; Francois *et al.*, 2005; Guillin, 2013), as the direct method requires extensive databases on regulatory regimes on services which have not, hitherto, been available (Jafari & Tarr, 2014). On the other hand, in the area of merchandise trade, this method has been applied to agri-food (Philippidis & Sanjuán, 2007a, 2007b), whilst the IMF (2002) have used this same approach to estimate the trade restricting effect of all non-tariff barriers in order to calculate 'trade potentials' for certain groups of countries. Following this same approach EP (2014) also calculate the trade potential between the EU and US after eliminating all possible trade barriers.

A comparison between both direct and indirect approach shows that the former provides a statistical assessment of the impact of non-tariff impediments to trade through examination of the dummy coefficient. Although this is not as straightforward in the indirect approach (Dean *et al.,* 2009), it is still possible (see next section). A further observation when inferring trade costs (*i.e.*, AVEs) using quantities, is the sensitivity of the AVE estimate to the value of the chosen import demand elasticity and/or elasticity of substitution. The direct price gap approach gets round this problem, as it allows the direct estimation of the impact of non-tariff impediments on prices. Finally, direct and indirect econometric approaches are susceptible to misspecification bias (*e.g.*, omitted variable bias), whilst it has been suggested that the accuracy of the non-tariff calculation in the residuals-gravity approach is potentially even more contingent upon the estimation technique and the quality of the model specification On the other hand, AVEs derived from non-tariff dummy variables depend crucially on the quality of the measurement of the non-tariff impediment under consideration (Ferrantino, 2006).

As stated in the introduction, an important aim of this research is to provide a platform upon which compatible measures of non-tariff trade costs may be implemented into modelling databases as a basis for conducting global trade impact analyses. To this end, the GTAP database is chosen with its broad, yet comprehensive, coverage of agri-food trade. Having taken the decision to employ this level of aggregation, we effectively rule out the use of non-tariff specific dummies, since at the GTAP sector concordance, at least one NTM will always be present, thereby resulting in a limited variability of observations[2].

Consequently, an indirect or residual quantity gap approach was favoured, whilst the approach adopted here is 'specific', in that it estimates non-tariff impediments to trade on a bilateral basis differentiating between intra- and extra-EU (*i.e.*, EU-US) trade routes. To provide statistical rigour often lacking in the indirect method (see discussion above), confidence intervals for bilateral non-tariff trade cost equivalents were calculated by bootstrapping, whilst pairwise t-tests for means were applied to test for statistically different AVEs across bilateral routes.

Model specification, data and estimation

In its simplest form, the gravity model posits that trade between two countries is a positive function of GDP (*i.e.*, 'mass') and a negative function of trade costs (*i.e.*, distance). Empirical applications have extended this basic premise to encompass (*inter alia*) preferential trade (*e.g*., Hayakawa & Yamashita, 2011), contiguity (*e.g*., Thoumi, 1989), common language and/or ex-colonial ties (*e.g*., Rose & van Wincoop, 2001), or even to cater for the effect of distance along different hemispheres as well as remoteness (*e.g*., Melitz, 2007). Other developments (*e.g*., Hallack, 2006) account for the so called 'Linder' (1961) hypothesis, which states that countries with similar *per capita* incomes have a greater tendency to engage in mutual trade. This is seen as a test of the monopolistic intra-industry hypothesis, whilst the polar opposite that differences in *per capita* incomes (which proxy for differing factor intensities) promote trade can be interpreted as support for the Hecksher-Ohlin (HO) hypothesis. This framework has also been extended to account for the role of infrastructure (Limão & Venables, 2001; Donaubauer *et al.,* 2016) and logistics performance indicators (Martí *et al*., 2014).

The general theoretically-consistent gravity equation derived by Anderson & van Wincoop (2003, 2004) is formulated as follows:

$$X_{ij} = \frac{Y_j Y_i}{Y_w}\left(\frac{t_{ij}}{P_j \pi_i}\right)^{1-\sigma} \qquad [1]$$

where X_{ij} are exports from country i to country j; Y_i and Y_j represent GDP, Y_w is world GDP, t_{ij} are trade costs *i.e.* $t_{ij} = 1 + \tau_{ij}$ where is an 'iceberg cost' imposed by country j on imports originating from country i; and σ is the elasticity of substitution between varieties (*i.e.* countries). The price index variables Π_i and P_j, denominated as 'multilateral resistance' terms, are a function of bilateral trade barriers (t_{ij}), and reflect the level of difficulty for country 'i' to engage in trade with country 'j', taking into account their bilateral trade barrier relative to the average trade barriers that both countries face with all their trading partners. Empirically, these unobserved terms are proxied with country specific dummies (Anderson & van Wincoop, 2004). Furthermore, provided that these variables do not change over the time horizon of the data, country-fixed effects may also capture consumers' preferences in the importing country or the number of varieties in the exporting country (Disdier *et al*., 2008).

In this study, a class of Poisson[3] gravity model was favoured (Santos Silva & Tenreyro, 2006, 2011) known as the Pseudo-Maximum Likelihood (PML)[4] estimator

[2] A possible alternative would be to employ a proportion index based on the share of NTM affected HS6 lines within each GTAP sector, although even in this case, existing databases (*i.e*., TRAINS) do not provide a complete picture for all countries. In this respect, the EP (2014) study reports that 100% of the HS6 agricultural and food product lines are affected by at least one NTM in OCDE countries, and accordingly, a direct NTM-dummy approach is confounded with the importer fixed effect.

(Gourieroux *et al.*, 1984). The model assumes that the observed volume of trade between countries i and j, X_{ij} follows a Poisson distribution with a conditional mean (μ_{ij}) which is an exponential function of the explanatory variables $\boldsymbol{z}$: $\mu_{ij} = exp(\boldsymbol{\beta}' z_{ij})$[5].

Time series trade data were obtained from UN ComTrade database (http://comtrade.un.org/), which has been widely used in the literature (Burger *et al.*, 2009; Fadeyi *et al.*, 2014; Serrano *et al.*, 2015). Thus, annual HS6 bilateral import trade values for the years 2001 to 2011, and 78 countries was collected and reconciled with the GTAP nomenclature of 18 agri-food sectors (Table 1) using WITS concordances (World Integrated Trade Solutions by WTO [http://wits.worldbank.org/wits]).[6]

Data on *ad-valorem* applied tariffs were taken from versions six (Dimaranan, 2006), seven (Narayanan & Walmsley, 2008), eight (Narayanan *et al.*, 2012) and nine of the GTAP database corresponding to the years 2001, 2004, 2007 and 2011, respectively. Population and GDP were from the World Bank (http://data.worldbank.org/data-catalog/world-development-indicators/wdi-2014), whilst data for cultural and geographical proximities was taken from CEPII (Mayer & Zignago, 2011).

Based on a review of the literature, a comprehensive gravity specification is formulated, and a full description of the variables is presented in Table 2. The explanatory variables of infrastructure and logistics were finally discarded owing to their incomplete country and/or temporal coverage from the available sources of data[7]. The Poisson regression model with an exponential mean function is presented in Eq. [2][8], where the sub-index i and j refer to the exporter and importer, respectively, whilst t refers to the year:

$$E[X_{ijt}] = \mu_{ijt} = exp\begin{pmatrix} \beta_0 + \beta_1 Mt_{ijt} + \beta_2 Dist_{ij} + \beta_3 DistInt_j + \beta_4 NoSo_{ij} + \beta_5 Lock_j \\ + \beta_6 Remote_{it} + \beta_7 Contig_{ij} + \beta_8 Lang_{ij} + \beta_9 Col_{ij} + \beta_{10} PTA_{ij} \\ + \beta_{11} SqIncome_{ijt} + \beta_{12} GDP_{ijt} + \sum_{t=2002}^{2011} \Theta_t Y_t + \sum_{i=2}^{N} \Theta_i F_i + \sum_{j=2}^{N} \Theta_j F_j \end{pmatrix} \quad [2]$$

Calculating trade barrier *ad-valorem* equivalents

In the indirect quantity gravity approach, discrepancies between actual (AX_{ij}, *i.e.* variable Xij in Eqs. [1] and [2]) and predicted (PX_{ij}, *i.e.* E[Xij] in Eq. [2]) values of trade are taken to be indicative of trade barriers, as the prediction by the gravity equation is assumed to reflect potential trade after controlling for observed trade frictions. Given that applied tariffs are included explicitly in the model, trade barriers implied by the residuals are considered to be due to non-tariff barriers. Thus, the trade cost t_{ij} in Eq. [1] (after controlling for observed trade frictions) is assumed to reflect the NTMs:

$$\left(t_{ij}^{NTM}\right)^{1-\sigma} = \left(1 + \tau_{ij}^{NTM}\right)^{1-\sigma} = {AX_{ij}}/{PX_{ij}} \quad [3]$$

where τ_{ij}^{NTM} is the AVE of all the NTMs imposed by country j on imports originating from country i.

Following Park (2002) and Francois *et al.* (2005), the AVEs are calculated by trading partner averaged over all import routes. Thus, in this study, for each country j, actual and predicted imports were summed over all its trade partners: $AX_j = \sum_{i=1}^{N} AX_{ij} \;\; i \neq j$ and $PX_j = \sum_{i=1}^{N} PX_{ij} \;\; i \neq j$ (in our application N<=78). In order to quantify the magnitude of the trade barriers, we also followed the aforementioned authors by normalizing each observed-to-predicted trade ratio with a benchmark of the largest ratio of observed-to-predicted trade, which is interpreted as a 'relative free-trade benchmark' ratio (AX_b/PX_b)[9].

Solving for the AVE of non-tariff measures (τ_{ij}^{NTM}) imposed by country j:

$$\tau_j^{NTM} = \left(\frac{AX_j/PX_j}{AX_b/PX_b}\right)^{1/1-\sigma} - 1 \quad [4]$$

In the current study, the interest lies in the specific non-tariff restrictions between the EU and US (*i.e.*, intra-EU; EU to US; US to EU), which in turn, requires a modification of Eq. [4]. For example, for EU imports of US goods, the AVE becomes:

$$\tau_{US\rightarrow EU}^{NTM} = \left(\frac{AX_{US\rightarrow EU}/PX_{US\rightarrow EU}}{AX_b/PX_b}\right)^{1/1-\sigma} - 1 \quad [5]$$

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[3] The Poisson estimator maintains the model in its multiplicative theoretical form (see Eq. [1]), thereby avoiding the coefficient bias within the log-linear transformation – the functional representation of Eq. [1] when employing Ordinary Least Squares (ECORYS, 2009), or the second stage of a Heckman approach (EP, 2014).

[4] Even when the dependent variable is not pure count, as it is the case of trade observations, the Poisson Maximum Likelihood estimator still provides consistent estimates (Woolridge, 2002).

[5] See Cameron & Trivedi (1998) for a detailed discussion of count models.

[6] The GTAP sectors of raw milk and raw sugar were discarded since they are classed as non tradables. The full list of 78 countries is available from the authors upon request.

[7] In particular, the coverage of the World Bank databases is limited. Thus, the length of railways is only available from 2006 onwards; data on paved roads is no longer publicly available; and the Logistics Performance Index is based on bi-annual surveys, starting from 2007.

[8] As a first step, we tested for possible endogeneity between tariffs and import volumes (*i.e.*, bilateral trade may explain bilateral import tariffs). Since the Wu-Hausman test failed to reject the null hypothesis that tariffs are exogenous [F (1, 394,447) = 0.220, p = 0.642], the subsequent analysis was conducted without taking into account instruments.

[9] Thus, by construction, the ad valorem trade cost is zero in the country that acts as the benchmark or reference point.

Table 1. Description of the 18 agri-food sectors

Code	Name of the sector	Definition
pdr	Paddy rice	Rice, husked and unhusked
wht	Wheat	Soft and durum wheat
gro	Other cereal grains	Rye, sorghum, barley, oats, maize, millet and other cereals
v_f	Vegetables, fruits and nuts	All vegetables, fruits and nuts
osd	Oilseeds	Oilseeds and oleaginous fruits
pfb	Plant based fibers	Raw vegetable materials used in textiles; seeds, live plants
ocr	Other Crops	Other crops
ctl	Cattle	Live bovine cattle, sheep and goats for fattening, horses, asses, mules
oap	Other animal products	Live swine and poultry for fattening, other animals; eggs, honey, snails and frogs legs
wol	Wool and silk-worm cocoons	Wool and silk worm cocoons
cmt	Meat of cattle	Meat of cattle, sheep, goats and horses
omt	Other meat products	Meat of swine, edible offal
vol	Vegetable oils and fats	Oils of: Coconuts, cottonseeds, groundnuts, oilseeds, olives, palm kernels, rice brans, rape and mustard, soyabeans, sunflower seeds; and fats
mil	Dairy products	All dairy products
pcr	Processed rice	Milled rice
sgr	Sugar	Refined sugar, sweeteners
ofd	Other food products	Prepared and preserved sea food products, vegetables and fruits, bakery and confectionary products, pastas and flours
b_t	Beverages and tobacco products	Cigarettes, cigars, wines and spirits, beer

where $AX_{US\rightarrow EU}$ ($PX_{US\rightarrow EU}$) adds up observed (predicted) imports coming from the US to any country in the EU: $AX_{US\rightarrow EU} = \sum_{j=1}^{k} AX_{US\rightarrow j}$ and $PX_{US\rightarrow EU} = \sum_{j=1}^{k} PX_{US\rightarrow j}$ (k=number of Member States in the EU).[10] Sectoral substitution elasticities (σ) across importing sources in [4] and [5] were taken from the GTAP database (Hertel *et al.,* 2007) and Kee *et al.* (2008).[11] In addition to the point estimates, confidence intervals for bilateral non-tariff trade cost equivalents were calculated.[12]

Results

The estimation of Eq. [2] was carried out on a sector-by-sector basis. Owing to considerations of space, further results can be found in the supplementary material (Table S1). Comparing with the relevant literature, the fit of the models, and parameter estimates were broadly in line with *a priori* expectations, exhibiting an acceptable level of statistical significance, whilst the relative magnitudes across explanatory variables were also consistent with previous studies.

In this section, several diagnostic comparisons were conducted to assess the plausibility of our non-tariff restriction estimates. First we compared non-tariff AVE estimates from relevant price- and quantity-gap studies in the literature. Secondly, estimated intra- and extra-EU non-tariff restrictions were compared, whilst additional match-ups were made with corresponding applied tariff AVEs from the GTAP database. Of particular interest we tested the *a priori* hypotheses (i) that harmonised 'single market' product standards and controls result in lower intra-EU non-tariff AVE estimates and (ii) that non-tariff restrictions are more trade prohibitive compared with traditional tariff measures.

[10] The composition of the EU changes over the sample period, being composed of 15 members prior to 2004, 25 countries between 2004 and 2006, and 27 from 2007 to 2011. Accordingly, the formula in [5] was calculated for each year in the sample, whilst the final estimate is the average.

[11] GTAP trade substitution elasticities were employed in the case of 'pdr' and 'ctl', owing to the abnormally low and high elasticity values, respectively, estimated by KNO.

[12] In particular, following Cameron & Trivedi (2010, Chapter 13) a non-parametric bootstrap-pair method was employed (*i.e.* both explanatory and dependent variable values are resampled together with replacement), clustered (*i.e.* resampling assumes independence of clusters of observations, where the cluster is defined by each pair of trade partners) and with, initially, 1000 replications. For each bootstrapped sample, the Poisson model was re-estimated which provided the necessary input to recalculate the bilateral AVE in Eq. [5]. Percentile bias-corrected (BC) confidence intervals were then computed (Cameron & Trivedi, 2010). The analysis was carried out employing STATA v.13.

Table 2. Variable descriptions in the Gravity equation

Variable	Description
X_{ijt}	Value of imports into country j from country *i* at current prices in year t (million US$)
Mt_{ijt}	Power of the import tariff rate (AdvRateijt) applied by importer *j* on imports from *i* in year *t*, measured in *ad-valorem* equivalents, in logs: $Mt_{ijt} = ln\left(1 + \frac{AdvRate_{ijt}}{100}\right)$
$Dist_{ij}$	Weighted bilateral distance by internal population, between the main cities of country *i* and *j*, in logs
DistIntj	Internal distance of country *j*, calculated as 0.67 $\sqrt{area_j/\pi}$, in logs
$NoSo_{ij}$	Difference in latitudes between countries *i* and *j*, in logs: $\ln(abs(latitude_i - latitude_j))$
$Remote_{it}$	Indicator of remoteness of country *i* in year *t*, calculated as a GDP weighted average of distance to the countries with which country *i* trades: $Remote_{it} = ln\left(\sum_{j}^{T(i)} \frac{GDP_{jt}}{GDP_{Wt} - GDP_{it}} \times Dist_{ij}\right)$ where $Dist_{ij}$ is the distance between *i* and *j* (defined as above), $GDPW_t$ is the world GDP in year *t*, and *T(i)* is the number of the destination countries of exports from *i*.
$Lock_i$	Dummy variable that values 1 when country *i* is landlocked, and 0 otherwise.
$Contig_{ij}$	Dummy variable that values 1 when countries *i* and *j* share a border, and 0 otherwise
$Lang_{ij}$	Dummy variable that values 1 when countries *i* and *j* share the same language (at least 9% of the population speaks it), and 0 otherwise
Col_{ij}	Dummy variable that values 1 when countries *i* and *j* have or have had a colonial linkage
PTA_{ijt}	Dummy variable that values 1 when countries *i* and *j* belong to the same Preferential Trade Area. PTA includes EU, EFTA, NAFTA, CEFTA (Central European Free Trade Agreement), Mercosur (Southern Cone Common Market), Andean Community, Caricom (Caribbean Community and Common Market), CACM (Central American Common Market) and ASEAN (Asean Free Trade Area).
$Sqincome_{ijt}$	Square of the difference in per capita income in countries *i* and *j*, in logs: $\ln((GDPpc_{it} - GDPpc_{jt})^2)$ with GDPpc measured in US$ per habitant (in nominal terms)
Gdp_{ijt}	Product of GDP in country *i* and country *j* in year *t*, in logs: $\ln(GDP_{it} \times GDP_{jt})$, with GDP measured in million US $ (in nominal terms)
Y_t	Fixed effect for each year t (t= 2002 to 2011), *i.e.*, a dummy variable that values 1 when the year is *t*, and 0 otherwise.
F_i (F_j)	Fixed effects for exporter (importer) country *i (j)*. $F_i(F_j)$ are dummy variables, that value 1 when the exporter (importer) is *i (j)*, and 0 otherwise

Comparing country- and sector-specific AVE estimates with the literature

Making comparisons with existing literature is complicated by the choice of sectorial and country aggregation, the estimation procedure, the quantification method and years of reference in the sample. Using WTO (World Integrated Trade Solutions-WITS) concordances between GTAP and HS6 codes, KNO (2009) arithmetic average AVEs for agricultural and food imports by GTAP sector were calculated (columns 3 and 6, Table 3) based on a sample of 61 countries which are common to both KNO and the current study.[13] The current study employed Eq. [4] to calculate country non-tariff AVEs which were later averaged for each GTAP sector (columns 2 and 5, Table 3).

Examining Table 3, our average estimate (second column) for both the agri-food and agricultural composites (25% and 30%, respectively) were very similar to the corresponding KNO estimates (31% and 25% - third column), whilst in the case of the aggregate food processing sector, the results were also broadly comparable (20% *vs* 34% - columns 5 and 6). On a sector-by-sector basis, KNO estimates for processed food products (except beverages and tobacco) were higher than those reported with our approach, while our estimates for agricultural products were higher in six out of ten sectors. In almost half of the sectors

[13] The full list of countries and calculations are available upon request from the authors.

Table 3. Comparison of *ad-valorem* equivalents (AVE) of aggregate NTMs by sector

	AVE [a]	KNO AVE [b]		AVE [a]	KNO AVE [b]
Agri-food	**0.25** [c]	**0.31**[d]			
Agriculture	**0.30**	**0.25**[d]	**Food**	**0.20**	**0.34** [d]
pdr	0.32	0.26	cmt	0.24	0.42
wht	0.40	0.16	omt	0.16	0.26
gro	0.14	0.27	vol	0.13	0.34
v_f	0.26	0.31	mil	0.23	0.51
osd	0.33	0.25	pcr	0.28	1.10
pfb	0.82	0.18	sgr	0.17	0.29
ocr	0.16	0.23	ofd	0.12	0.35
ctl	0.13	0.31	b_t	0.25	0.20
oap	0.26	0.17			
wol	0.13	0.03			

[a] Estimates using the indirect residual approach. Averages across 61 countries common to the KNO (2009) database. [b] Own calculations based on KNO (2009) database, using both, Core NTB and Agricultural Domestic Support. GTAP sectoral figures were obtained averaging original AVEs for HS6 sectors and individual (61) countries. Calculus based only on Core NTB did not change the reported values substantially. [c] Simple average over GTAP sectoral averages. [d] Simple average over original HS6 sectors and individual countries.

examined, the gap in mean AVE estimates between both approaches was less than 10 percentage points, with a minimum difference of 5 percentage points for fruits and vegetables and beverages and tobacco. In the case of food processing, the largest difference can be found in processed rice (110% versus our estimate of 28%). In agriculture, the main differences occured in plant based fibres (18% versus our estimate of 82%).

As a further basis of comparison, Table 4 compares our country specific estimates (columns 2 and 6) from Eq. (4) with two quantity gap studies (KNO, 2009; EP, 2014) and the price gap approach of Bradford (2003). In the case of agriculture, our non-tariff AVE estimate for the US and EU-27 was 27% and 29%, respectively. This is broadly compatible with corresponding estimates of 22% and 27% in KNO and 33% and 44% in EP (2014). Across the same three quantity gap studies, the divergence was higher for processed food, where KNO estimates were placed around the midpoint between the lower values in the current study and upper values of EP (2014). Despite the use of a different methodology, EU non-tariff AVE estimates in Bradford (2003) converged closely with the three quantity gap studies, whilst in common with our results Bradford (2003) concludes that agricultural non-tariff restrictions are more prohibitive than those of food in both the EU and US. Remarkably, all four studies conclude that 'behind the border' trade costs in the EU are more prohibitive than those of the US, although this finding is not consistent with non-tariff estimates of 'food processing' reported by OECD (2011) (30.1% and 49.5%, for EU and US, respectively).[14]

Bilateral (EU-US) non-tariff AVE estimates

In a next step, Eq. [5] was employed to calculate non-tariff AVEs on intra-EU and trans-Atlantic trade in both directions (Table 5). The point AVE estimates reported here for (trade weighted) agri-food imports to the EU from the US (35%) and to the US from the EU (27%) are lower than those reported by ECORYS (2009) (56.8% and 73.3%, respectively). Apart from the different sectorial coverage and disaggregation, differences in results are also attributed to the choice of data, econometric estimator and modelling approach. Our estimates are more in line with those of EP (2014). Thus, examining the simple average agri-food estimates in our study, we estimated AVEs of 47% and 39% for the EU and US, respectively, compared with corresponding estimates in EP(2014) of 54% and 48%.[15] Encouragingly, across the three bilateral routes, AVE point estimates for the 'agri-food' aggregate moved within the range of 17% to 35% (Table 5), which is more in line with the value of 31% reported by KNO (see Table 3). In addition, our AVE point estimates for extra-EU imports were 38% (agriculture)

[14] It should be noted that the aggregate NTM estimates for the EU in Table 4 from our study also reflected intra-EU trade which is typically characterised by lower NTM trade costs (see the following subsection).
[15] The calculations were based on the simple average of the AVEs for 14 agri-food sectors reported in Table 2.9 of EP (2014).

Table 4. Comparison of *ad-valorem* equivalents (AVE) of NTMs by country

	Agriculture				Food			
	AVE	**KNO AVE**[a]	**Bradford AVE** [b]	**EP AVE** [c]	**AVE**	**KNO AVE**[a]	**Bradford AVE**[b]	**EP AVE** [c]
Australia	0.24	0.30	0.07	na	0.20	0.53	0.09	na
Canada	0.29	0.24	0.11	na	0.19	0.22	0.20	na
Japan	0.27	0.27	0.58	na	0.19	0.40	1.10	na
US	0.27	0.22	0.16	0.33	0.19	0.31	0.10	0.53
EU-15	0.28	0.33	0.35	---	0.19	0.50	0.33	---
EU-27	0.29	0.27	---	0.44	0.19	0.40	---	0.64

[a] Own calculations based on KNO (2009) database, using both, Core NTB and Agricultural Domestic Support. Simple averages across HS6 sectors (and countries in EU aggregates). Due to country coverage, EU-15 does not include Luxembourg, and EU-27, Luxembourg, Bulgaria, Cyprus, Croatia, Malta and Slovakia. [b] Own calculations based on Bradford (2003, Table 2). EU-15 based on results reported for Belgium, Germany, Netherlands and UK (simple average). Agriculture includes fisheries and forestry, and Food excludes beverages and tobacco. Adding AVEs of fisheries and forestry to Agriculture weighting by trade, led to small changes in comparison to the figures reported in column 5. [c] Own calculations based on EP (2014, Table 2.9). na: non-available.

and 32% (food), which compares favourably with the corresponding extra-EU estimates by KNO (Table 4) of 27% and 40%. A similar observation is true for the US's imports.

Examining intra-EU trade for primary agricultural commodities (Table 5), the trade weighted AVE mean estimate was 23%. Moreover, individual sector estimates ranged between 15% and 19% in the broad (heterogeneous) sectors of 'other crops' and 'other grains', to 48% in 'cattle and sheep' and 63% in 'plant based fibres' (Table 5), whilst in the case of intra-EU processed food trade, the AVEs were of a lesser magnitude and more homogeneous in magnitude across sectors. On trans-Atlantic trade routes, the US was estimated to impose AVEs as high as 91%, 82% and 71% on imports of 'cattle meat', 'plant based fibres' and 'dairy', respectively. In turn, the EU AVE peaks were apparent on imports of 'dairy' (90%), 'cattle meat' (71%) and 'pig/poultry meat' (63%).

Comparing across the three bilateral routes, with the exceptions of 'oilseeds', 'cattle' 'wool', and 'beverages and tobacco', the AVE was found to be lowest on the intra-EU trade route (as expected). In addition, in those sectors where US non-tariff AVEs are deemed higher than their EU equivalents (*i.e.*, 'cattle meat', 'processed sugar' and 'processed rice'), with the exception of the latter, the result was found to be statistically significant. In the case of 'vegetables and fruit', despite the close AVE estimates of 35-36% in both directions, a t-test of the mean bootstrapped values revealed that the US AVE was higher; a result supported by the higher upper limit within the US confidence interval (see below). In the majority of sectors (14), the results appeared to indicate that EU AVEs are equally or more prohibitive than those of the US, which further supports the observation made at the end of the previous section (Table 4). On the other hand, pair-wise t-tests showed that this finding is only supported statistically in eight of those sectors (*i.e.*, 'other grains', 'oilseeds', 'plant based fibres', 'other crops', 'white meat', 'vegetable oils', 'dairy', 'beverages and tobacco'). Moreover, when testing for differences in the trade weighted AVE means on trans-Atlantic routes for agriculture, food and agri-food categories, no statistical difference was found. Interestingly, EP (2014) also reports this same finding.

The calculation of confidence intervals helped to capture the degree of certainty behind the AVE point estimates over a time period of the sample. Inspecting the results in Table 5, EU AVE point estimates, particularly on intra-EU trade, exhibited greater accuracy than those of the US. On closer inspection of the data, there were cases of small import trade flows (owing to high self-sufficiency) accompanied by significant import volatility (particularly on (*inter alia*) 'other grains' and 'processed sugar' trade from the EU to the US), whilst in other sectors (*e.g.*, vegetable oils and fats trade from the EU to the US) the presence of a structural break was observed relating to an array of indeterminate sector specific events (*i.e.*, weather shocks, agricultural policies, data aggregation).

Comparing between (trade weighted) non-tariff and tariff AVE's on EU-US bilateral trade (Table 5), for the selection of agri-food products under consideration (with one exception[16]), NTMs (as expected) were found to be more trade prohibitive on trans-Atlantic imports in

[16] In the case of EU imports of US processed sugar, the NTM and tariff AVEs are 13% and 19%, respectively.

Table 5. NTM AVE estimates and AVE Tariffs for bilateral trade EU-US (95% confidence interval in parentheses)[1,2,3]

Sector	EU→EU	US→EU		EU→US	
	NTM	NTM	Tariff [5]	NTM	Tariff [5]
Agriculture (trade weighted mean)[4]	**0.23 [a] (0.18, 0.27)**	**0.38 [b] (0.33, 0.43)**	**0.03**	**0.30 [ab] (0.22, 0.38)**	**0.02**
pdr	0.22 (na)	0.39 (na)	0.21	0.36 (na)	0.01
wht	0.29 [a] (0.27, 0.29)	0.41 [b] (0.34, 0.49)	0.12	0.39 [b] (0.00, 0.61)	0.01
gro	0.19 [a] (0.13, 0.32)	0.36 [b] (0.22, 0.38)	0.01	0.33 [c] (0.23,0.80)	0.00
v_f	0.22 [a] (0.19, 0.22)	0.35 [b] (0.20, 0.44)	0.03	0.36 [c] (0.12, 0.57)	0.02
osd	0.33 [a] (0.21, 0.41)	0.42 [b] (0.27, 0.53)	0.00	0.16 [c] (0.00, 0.40)	0.00
pfb	0.63 [a] (0.48, 0.74)	1.33 [b] (0.89, 1.89)	0.00	0.82 [c] (0.10, 1.49)	0.00
ocr	0.15 [a] (0.15, 0.18)	0.30 [b] (0.18, 0.46)	0.06	0.23 [c] (0.18, 0.32)	0.03
ctl	0.48 [a] (0.41, 0.55)	0.35 [b] (0.03, 0.42)	0.03	0.34 [b] (0.11, 0.45)	0.03
oap	0.24 (na)	0.54 (na)	0.02	0.44 (na)	0.00
wol	0.26 (na)	0.31 (na)	0.00	0.17 (na)	0.01
Food (trade weighted mean)[4]	**0.15 [a] (0.10, 0.19)**	**0.32 [b] (0.25, 0.38)**	**0.13**	**0.27 [b] (0.17, 0.36)**	**0.02**
cmt	0.20 [a] (0.18, 0.21)	0.71 [b] (0.50, 0.97)	0.64	0.91 [c] (0.39, 1.92)	0.01
omt	0.13 [a] (0.11, 0.13)	0.63 [b] (0.45, 0.78)	0.15	0.24 [c] (0.10, 0.47)	0.01
vol	0.10 [a] (0.10, 0.10)	0.46 [b] (0.30, 0.54)	0.03	0.38 [c] (0.16, 0.79)	0.01
mil	0.18 [a] (0.16, 0.18)	0.90 [b] (0.48, 1.17)	0.47	0.71 [c] (0.46, 1.17)	0.12
pcr	0.20 (na)	0.33 (na)	0.21	0.44 (na)	0.04
sgr	0.13 [a] (0.11, 0.13)	0.13 [b] (0.00, 0.25)	0.19	0.31 [c] (0.10, 0.44)	0.12
ofd	0.11 (0.09, 0.12)	0.27 [b] (0.17, 0.36)	0.13	0.27 [b] (0.17, 0.36)	0.04
b_t	0.21 [a] (0.16, 0.31)	0.33 [b] (0.18, 0.60)	0.06	0.21 [a] (0.16, 0.32)	0.01
Agric + Food (trade weighted mean)[4]	**0.17 [a] (0.12, 0.21)**	**0.35 [b] (0.30, 0.40)**	**0.08**	**0.27 [b] 0.18, 0.35)**	**0.02**

[1] AVEs based on KNO (2008) elasticities of substitution, with the exception of 'pdr' and ´ctl´, where the GTAP elasticity is used. [2] 95% confidence interval (CI) (percentile bias corrected) using bootstrap. Although the initial number of replications was 1000, model convergence failure reduced the actual number to a range between 400 and 800, depending on the sector, with a mean of 500. For agriculture and food aggregates the CI was based on a t-student distribution. [3] Pairwise t-tests for the means across different bilateral routes used bootstrapped coefficients. Means within a row with different letters a,b,c are significantly different at 1%. [4] Weighted average by mean trade values in the sample period, 2001-2011. [5] Calculated from version 9 of the GTAP database. na: non-available

both directions. For aggregate agricultural imports, the tariff and non-tariff AVEs for the EU (US) were 3% and 38%, (2% and 30%), respectively. In the case of food, the corresponding estimates were 13% and 32% (2% and 27%), respectively. This finding reinforces the view expressed in the introduction that non-tariff restrictions have replaced tariffs as the dominant form of (agri-food) trade protectionism.

Discussion

From a policy perspective, the credibility of bilateral non-tariff AVE estimates is very much a function of the sector under analysis. In both meat sectors, the relatively high non-tariff AVEs are entirely consistent with rigorous control standards and even import restrictions imposed by both the EU and US. In the case of 'cattle meat', high non-tariff AVEs in both partners is perhaps to be expected given EU import quota regulation, heavy SPS regulatory barriers and the retaliatory history of trade in this sector. Indeed, on the latter point, the long serving EU restriction on cattle meat treated with growth promoting hormones has been met by US sanctions on EU origin beef. It is only more recently, within the TTIP negotiations that the EU agreed to authorise the US's use of lactic acid in meat preparations.

In the pig/poultry meat sector, the finding that the EU imposes higher non-tariff costs may be partly explained by its ban on the use of pathogen reduction treatments of poultry carcasses. Moreover, there has been ongoing concern within the EU regarding the compulsory usage of origin labelling and traceability for fresh and frozen poultry meat, which presents an important additional trade cost.[17] In addition, the AVE estimate presented here (63%) for white meat trade from the US to EU coincides with the lowest estimate for pork reported by Arita *et al.* (2015). On the other hand, the EP (2014) estimate for white meat (82%) is closer to our upper limit (78%).

In the live 'cattle' (principally live bovine, ovine and equine) and 'other animal products' (principally live swine and poultry) sectors, the high AVEs reported for both partners (Table 5) are compatible with significant transport costs related to the application of mandatory requirements governing animal welfare. The result for 'ctl' concurs with the estimates from EP (2014) (38% and 22% in the EU and US, respectively), both of which fall within our confidence interval. Notwithstanding, in live cattle, there is an apparently counter-intuitive result that the intra-EU bootstrapped estimate (48% - Table 6) is statistically higher than the extra-EU and US import equivalents. In any case, it remains unclear as to whether significant live animal trade would occur under a hypothetical TTIP agreement.

On dairy trade, the twenty percentage point gap reported in Table 5 between the US and EU is questionable, despite the statistically significant difference in bootstrapped means. On the other hand, our point estimates reported in Table 5 are remarkably close to those in EP (2014) (92% and 68% for EU and US, respectively). On both sides of the Atlantic, a system of dairy tariff rate quotas (TRQs) is imposed, whilst it is true that the EU imposes considerable administrative burdens relating to (*inter alia*) milk quality requisites (somatic cell counts), and the usage of geographic indicators (*i.e.*, parmesan, feta etc.) (USDEC, 2013). Notwithstanding, interstate sales of EU origin pasteurised milk products (known as 'Grade A' milk produce) are heavily complicated by numerous rules of compliance with US regulations. In its qualitative survey, ECORYS (2009) classifies these non-tariff restrictions as highly prohibitive to EU sales, which explains why the EU sought after an acceptance of equivalence in order to permit exports of EU Grade A milk produce to the US. In addition, from 2011 onwards, the Dairy Promotion Program (DPP) in the US has levied an additional charge on imported dairy products, which in turn finances promotion, education and research programs, although it remains unclear as to whether this measure benefits imported dairy products.

The fruit and vegetable market in both partners is also subject to strict quality control programs. This is reflected by notable AVE estimates on both sides, whilst the US AVE is found to be statistically higher, as noted above. Importantly, our AVEs are comparable to the estimates in Arita *et al.* (2015, Table 11, pp20) for fruits and vegetables. EU imports from third countries must comply with the harmonisation of maximum residue limits for pesticides and strict requirements regarding traceability, whilst the US also imposes stringent inspection programs. For example, the US Agricultural Marketing Agreement Act of 1937 establishes different marketing orders of particular relevance to fruits and vegetables (TRALAC, 2010).

On cereals trade, the point estimates for wheat are statistically the same, whilst for 'other grains', EU non-tariff restrictions were found to be more trade prohibitive. In the latter case, this result is perhaps not surprising, since US exports of 'other grains' to the EU (principally maize) are subject to strict monitoring for genetic modifications (USTR, 2007), whilst the EU imposes a TRQ scheme on grain imports. On EU imports of wheat, EU tolerance limits on mytoxins are lower than in the US which could be a significant hindrance to US exporters.[18] For its part, US policy bestows significant behind the border competitive advantages to cereal producers in the form of marketing assistance, storage facility loans and insurance subsidies (TRALAC, 2010). In the case of oilseeds trade, the EU non-tariff AVE is considerably higher than the US equivalent which is consistent with the EU's adherence to stringent GM regulations on imports of soybeans and linseeds.

The fact that the quantitative results suggest that the US is the more prohibitive on imports of processed rice and sugar is also open to debate. The non-tariff restrictions on both sides reflect, in part, the quantitative restrictions under the tariff-rate-quota regime for both commodities. On the other hand, the EU once again imposes further controls on its GM sugar and rice

[17] Based on the willingness of the US chicken and pork industries to adapt to EU production standards, it has been suggested (Arita et al., 2014), that a relaxation of the EU's tariff rate quota scheme would perhaps not have such a significant impact on US chicken exports, whilst in the pork sector, a clear rise in exports could be expected

[18] This also affects US exports of almonds and peanuts in the GTAP aggregate, 'vegetables, fruits and nuts'.

[19] A genetically modified strain of rice known as LibertyLink rice was developed by an eventual parent company known as Bayer CropScience. The rice was genetically modified to be tolerant to glufosinate, the active ingredient in Liberty herbicide, although in 2006 it was discovered that trial tests of this rice had contaminated the US rice supply.

imports, particularly in the case of the latter.[19] Finally, on beverages and tobacco trade, the US imposes severe cross state retailing and distribution red tape restrictions on EU products (ECORYS, 2009), whilst the geographical indicator (particularly for wine) which receives much attention within the EU, is not given due consideration by US authorities. As a caveat, one should exercise caution when interpreting a single non-tariff AVE estimate for this broad sector (*i.e.*, soft drinks; alcohol, wines, spirits and tobacco etc.). Similar caution should also apply in the case of the 'other food' processing estimates.

Conclusions

The year 2013 signalled the opening of negotiations between the world's two largest trading partners, the European Union (EU) and the United States (US). Unfortunately, conventional impact studies are ill equipped to assess the potential economic gains due to the lack of any coherent and consistent database relating to non-tariff restrictions. Indeed, unlike conventional tariff measures, non-tariff impediments to trade do not have a transparent price effect which can be readily inserted into an economic model and consequently there is uncertainty in policy circles regarding the real trade cost of 'behind the border' measures.

To empirically answer this question, the gravity model has received recognition as a vehicle for understanding the trade restrictive impact of non-tariff measures. To complement and deepen previous gravity studies in the literature, this study provides comprehensive bilateral EU-US non-tariff *ad valorem* equivalent (AVE) estimates for 18 disaggregated agriculture and food activities. Indeed, in comparison with ECORYS (2009) and EP (2014), it takes further steps either in terms of the methodological approach adopted; or the level of agri-food sectoral coverage; or the decomposition of NTM AVE estimates by intra-EU and trans-Atlantic bilateral trade routes. As a means to providing accessible non-tariff AVE estimates compatible with the typically more aggregated sectoral concordance found in global modelling databases, this explorative research proposes an 'indirect' gravity approach.

As an initial conclusion, the magnitudes of the non-tariff AVEs estimated for both partners suggests that in the 'cornerstone' sectors of (*inter alia*) meat, dairy, cereals and vegetables and fruit, substantial trade led opportunities and threats could emerge if, under the auspices of the TTIP, both partners arrive at a common terms of reference for the harmonisation of 'behind the border' measures. In an attempt to further assess the credibility of the estimates, comparisons are made employing a number of approaches. As expected, the magnitudes of the NTMs are found to be higher than those of the tariffs, confirming the expectation that non-tariff impediments have replaced tariff barriers as the main form of trade protectionism (Hummels & Schaur, 2013).

Comparing with the literature (Bradford, 2003; KNO, 2009; EP, 2014), the results are broadly comparable, although most strikingly, there is a consensus that the EU imposes more prohibitive agri-food NTMs than the US. In many sectors, the results appear to be credible (*i.e.*, cattle meat, pig/poultry meat, fruit and vegetables, cereals). Elsewhere, the general magnitudes appear to be plausible, although it is debateable whether the EU or US AVE should be more restrictive (*i.e.*, dairy, processed rice and sugar). For some specific bilateral routes there are some counterintuitive results coinciding with those sectors where relatively small and volatile trans-Atlantic trade flows are observed. In addition, estimation difficulties were encountered where there are (unexplained) structural breaks within the data. In recognition of these issues, a bootstrapping procedure was employed to generate confidence intervals in order to assess the reliability of each bilateral AVE point estimate. Notwithstanding, further work could be focused on improving the sector specificity of each gravity equation to better capture observed trade trends, thereby improving the model's predictive capacity.

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