HOW MUCH DO NON-TARIFF MEASURES COST?
A SURVEY OF QUANTIFICATION METHODS

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Abstract

The effect of non-tariff measures on trade is a growing area of interest in international trade research. In recent years, numerous methodologies have been proposed for estimating the trade costs associated with non-tariff measures. In this paper, we survey a collection papers proposing differing methodologies for quantifying the associated ad valorem equivalent trade costs. For each of the papers, we explore the key features of the methods such as data inputs, identification strategies, and econometric specifications. We conclude by providing a table of estimated non-tariff trade costs faced by exporters to the United States from these studies for a wide collection of goods and services industries.

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1 Introduction

Understanding the effect that non-tariff measures (NTMs) have on international trade has become an area of increasing interest in recent years. As tariff rates reach historic lows, policy discussions have increasingly turned to other policy measures that influence trade. These measures are expansive, including policies such as administrative procedures, technical regulations, sanitary and phytosanitary measures, customs and border procedures, financial regulations, domestic subsidies, and quantity restrictions. That these types of measures affect trade is well documented, but the extent to which they do is less well understood. Tariffs, by comparison, are concretely defined (typically by a specific rate) and lend themselves well to quantitative economic analysis. NTMs, on the other hand, are typically not so cleanly defined in terms of ad valorem impacts on trade costs, making quantitative assessment much less straight forward. Considerable effort has been expended by researchers trying to develop methods for quantifying the impacts of NTMs through the estimation of an ad valorem equivalent (AVE).[1] In this paper, we survey a collection of these methods and explain the ways in which they attempt to identify NTMs and quantify their associated trade costs.

Estimates of AVEs are of considerable interest for several reasons. For one, an AVE provides an easy to interpret value that permits the direct and numerically meaningful comparison of differing NTMs or NTM environments. Additionally, other areas of research such as general or partial equilibrium modeling rely on specific tariff rate values within their applications. In order to simulate the removal of an NTM, a tariff rate equivalent must be specified as a part of the calibration. Thus, the estimation of an accurate one is desirable. Knowledge of AVEs is also useful from a policy perspective. Preferential trade agreements (PTAs), for example, have increasingly focused on the loosening of NTM restrictions in recent years (see Neufeld (2014) and Hofmann et al. (2017)). Such a discussion requires that the impact of the NTMs in question be understood so that negotiators or policymakers fully understand what is at stake.

There is much discussion in the literature about the role of NTMs as a part of a country's regulatory environment. Unlike tariffs, which are unambiguously intended to reduce the imports of a targeted good in most cases, NTMs may exist for a variety of reasons. In many cases, measures perform a socially desirable function such as preventing the spread of disease or upholding an environmental standard. In these cases, the trade reducing aspects of the measure must be balanced against the social good that it is fulfilling. In other cases, however, the measure may exist for the purpose of restricting trade or may restrict trade more than is necessary for the fulfillment of the desired social function. In these cases, the measures are often referred to as non-tariff barriers (NTBs). Much of the work that is surveyed in the following sections uses this terminology but we have chosen to exclusively use the less restrictive term NTM. By using NTM instead

[1] AVEs are also often referred to as tariff rate equivalents (TRE).

of NTB, we avoid discussion or implicit judgment over the intended purposes of any measures and focus instead on the broad quantification of NTMs, regardless of their intentions.

Before examining each chosen methodology in detail, it is worth discussing the types of methodologies present in the literature in general. This work typically falls into one of three possible approaches for the identification of AVEs: price gaps, value gaps, and quantity gaps.

Because AVEs are sought, a method that uses differences in prices is a natural approach to quantification. If the price of a good is twenty percent higher in the presence of a particular NTM, all else equal, the AVE of the measure is simply twenty percent. Methods that identify price gaps that are attributable to NTMs, such as Dean et al. (2009) and Dee (2005) described below, are intuitively appealing and require few assumptions when constructing the AVEs. However, the limited availability of accurate cross-country price data at a sufficiently granular level that permits the study of NTM trade costs has dampened the wide-spread use of price gap methods.

The use of trade value based approaches (price $\times$ quantity) have been more widely adopted, due in part to the availability of data on trade values. Value approaches, such as those in Park (2002), Fontagné et al. (2011), Berden et al. (2009), Egger et al. (2015), and Kee et al. (2009) described below, use estimated gaps in trade values to infer NTM AVEs. These methods largely use gravity models to estimate the extent to which the presence of NTMs reduces trade flows compared to a "free trade" environment. They then infer the AVE trade cost that would result in the observed level of trade compared to the expected "free trade" level.

Finally, a third option exists in which gaps in quantities traded are used to infer AVEs. AVEs are constructed in a way similar to those for value gaps by comparing traded quantities with and without the NTMs. Quantity based methods are relatively uncommon in the literature and are not surveyed to any significant extent in any of the sections to follow. Nonetheless, they are worth mentioning because they are used occasionally. For example, one of the models estimated by Dee (2005) uses quantity gaps. Similarly, work by the U.S. International Trade Commission has used a quantity gap approach for special cases in which pricing data are not available (see U.S. International Trade Commission (2009, p.H-9), for example).[2] Because of their relative absence in the literature, we will not dedicate additional attention to quantity gaps.

The remainder of the paper surveys a collection of methods for estimating the AVE trade costs associated with NTMs. While this list is not exhaustive, it does cover many of the seminal papers in the field and demonstrates the prominent methodological directions that researchers have taken. We divide the research into three broad approaches and include sections for each.

The first of these sections (section 2.1) surveys two papers that attribute unobserved trade frictions to

[2] In these two reports, knowledge of import shares relative to total foreign supply are used to measure the quantity gap.

NTMs and use unexplained variation within gravity models to quantify NTM trade costs. The first paper by Park (2002) estimates AVEs through regression residuals. The second paper by Fontagné et al. (2011) uses country-level fixed effects to construct AVEs.

The second section (section 2.2) looks at several papers that quantify NTM costs using NTM indices that reflect the restrictiveness of an NTM environment. In most cases, these NTM indices are based on qualitative, survey generated data about the NTMs faced by firms in different markets. The first paper by Dee (2005) proposes a collection of industry-specific, partial equilibrium models and estimates AVEs from sector-level NTM indices. The second paper by Fontagné et al. (2011) uses survey data within a gravity model to study E.U.-U.S. regulatory differences. The final paper by Egger et al. (2015) follows a similar approach using an index of the NTM provisions in preferential trade agreements to infer the value of their removal within a gravity framework.

The third section (section 2.3) examines two papers that use actual data on the incidence of NTMs to identify and quantify their effects. The first of these papers by Kee et al. (2009) uses a product-level econometric approach that features tariff-line data on NTMs. The second paper by Dean et al. (2009) uses retail pricing data and disaggregated NTM data to measure NTM-related price gaps.

Section 3 provides a table composed of the estimated AVEs for the United States from each of the seven surveyed papers. The final section concludes.

2 Methodologies

2.1 Inference from Unobservables

One approach to identifying the effects of NTMs is based on attributing unobserved variation in trade to NTMs. Under this approach, standard econometric models used to explain trade flows (predominantly gravity models) are estimated with a collection of standard barriers to and facilitators of trade such as distance, shared borders, and trade agreements. However, this collection of explanatory variables is generally unable to explain all the variation in the data. If measures of NTMs are not included in the specification, the remaining variation is a result, at least to some extent, of NTMs. If it is assumed that this unobserved variation in the value of trade is predominantly the result of unaccounted for NTMs effects, then the magnitude of these effects can be inferred based on this variation. The following two papers demonstrate two methods of doing so using regression residuals and fixed effects, respectively.

2.1.1 Inference from residuals: Park (2002)

Park (2002) represents a relatively early attempt to quantify the effects of non-tariff measures. At the time, the work aimed to fill a gap in the literature concerning barriers to trade in services. Services, unlike goods, are generally not subject to tariffs, implying that NTMs are the primary barriers to trade that they face. As a result, the interest in the effects of NTMs holds a special importance in the study of determinants of trade in services. Park notes that information on these effects is limited, highlighting work by Hoekman (1995), Hardin and Holmes (1997), and Bosworth et al. (2000) that produced subjective so-called "guestimates" of the effects. Diverging from this line of research, Park focuses on novel work by Francois (1999) that used a gravity model to estimate tariff equivalents of NTMs for bilateral trade between the United States and its trading partners in the construction and finance sectors. Park (2002) extends Francois' approach to a larger collection of fifty-one countries and seven service sectors.[3]

The methodology is based on a typical gravity specification, which is estimated using bilateral trade data from the GTAP database (1997 edition).[4] The econometric model takes the form

$$lnx_{ij} = c + \beta_1 lny_i + \beta_2 lny_j + \beta_3 lnd_{ij} - \beta_4 lnP_j^{1-\sigma} - \beta_5 ln\psi_i + \sum_k \gamma^k z_{ij}^k + \epsilon_{ij}. \tag{1}$$

Here, x_{ij} denotes bilateral trade flows from exporter i to importer j, y denotes importer and exporter GDPs, d denotes bilateral distance, and z^k consists of a collection of standard gravity variables such as common language and contiguity. The terms P and ψ denote aggregate price indices that are meant to proxy for multilateral resistance and σ represents the elasticity of substitution. Finally, there is the error term ϵ, which represents the difference between the expected level of trade given the chosen independent variables and the observed level of trade.

It is through this error term that Park seeks to identify the effect of NTMs. Following the estimation of the gravity model, the residuals are examined and compared. Country-pairs that exhibit large, positive residuals are those that trade above their expected amount given the other explanatory variables while small or negative residuals represent the opposite. Here, NTMs are assumed to be the remaining unobserved influences on trade flows, implying that differences in the residuals are the result of differing levels of NTMs. Thus, the importers with large, positive residuals are those that feature less onerous importer NTMs. Following this logic, the residuals can be used to calculate AVE trade costs for the underlying NTMs. To do so, Park compares the actual value of imports to a predicted value of imports were there no NTMs in place. Using the difference between these import values, it is possible to calculate the AVE trade cost that would have

[3]The seven service sectors are construction, trade, transport, communication, financial, business, and others.
[4]For a general introduction to gravity modeling, see Head and Mayer (2015).

resulted in this disparity from the expected free trade outcome. Specifically, the AVE rate can be computed using the equation:

$$-\sigma \ln AVE_j = \ln(X_j^{actual}/X_j^{predicted}) - \ln(X_{benchmark}^{actual}/X_{benchmark}^{predicted}). \quad (2)$$

This calculation relies on two assumptions. The first assumption concerns the estimation of NTM-free trade. It is not possible to observe what import levels would be in the absence of NTMs, thus a proxy must be chosen. In this case, the least restrictive country (i.e. the country with the largest positive residuals) is designated the benchmark "free trade" country and all other countries are compared to it.[5] Thus, in equation (1), the actual and predicted import values for a country j are denoted by X_j while those for the benchmark, "free trade" country are denoted by $X_{benchmark}$. The second assumption concerns the elasticity of substitution σ, which must be chosen. This parameter, which is not estimated as a part of the econometric procedure, specifies the responsiveness of trade to trade costs. Park selects a value of 5.6 based on estimates from Feenstra (1994) and Hummels (1999). The selection of this value is subject to scrutiny as its magnitude affects the calculated AVE rate. However, it is worth noting that this parameter does not impact the relative ordering of countries with respect to NTM restrictiveness so there is useful information in the results regardless of the assumed elasticity.

The results of this procedure provide country-level estimates of AVEs of NTMs for the fifty-one countries and seven sectors considered. Estimates for the United States, for example, range from about three percent for "other" services to fifty-two percent for "trade" services. For this paper and each to follow, a full collection of estimates can be found in table 1.

The residual approach has been further used in numerous papers since Park (2002), including Francois et al. (2005), Philippidis and Sanjuán (2007a), Philippidis and Sanjuán (2007b), and Guillin (2013). Guillin, for example, uses gravity equations with similar control variables to those used by Park to estimate AVEs for over sixty countries and for eleven service sectors. Additionally, Guillin expands on Park's original model by accounting for cases of zero flows of trade.

2.1.2 Inference from fixed effects: Fontagné et al. (2011)

The work by Fontagné et al. (2011) is in many ways a direct extension of that conducted by Park (2002). Much of the paper is focused on assessing potential methodological issues arising from the use of gravity models for AVE estimation of NTMs. In particular, the authors express concerns over the specification used by Park (2002) and propose an alternative methodology and data source. They present and contrast

[5] In the paper, the benchmark countries consisted of Hong Kong, Australia, the Philippines, and Singapore, depending on the sector.

AVE estimates using several combinations of differing model specifications and data sets in order to evaluate the robustness of the work and eventually arrive at a preferred specification using country fixed effects for inference of NTM trade costs.

The methodological analysis represents the largest contribution of the paper. Fontagné et al. note that the methodology used by Park (2002) is subject to several potential problems. First, the use of residuals for identification of NTMs likely exhibits considerable omitted variable concerns. Second, the earlier work is based on GTAP data that is partially reconstructed through simulation methods to fill gaps in missing services data.[6] They address the first issue by comparing a collection of gravity models resembling Park's specification to an alternative specification using country-level fixed effects to identify NTM effects. Second, they compare estimates using 2004 GTAP data to estimates using OECD data that does not exhibit any reconstruction and provides multiple years of observations in a panel.

The first collection of models that Fontagné et al. consider (1.1, 1.2, and 1.3 in their study) are meant to replicate Park (2002). They take the form

$$\ln x_{ij} = c + \alpha_1 \ln y_i + \alpha_2 \ln y_j + \alpha_3 \ln P_j + \alpha_4 \ln P_i + \alpha_5 \ln d_{ij} + \sum_k \alpha_{ij}^k z_{ij}^k + \epsilon_{ij}. \tag{3}$$

As before, y_i and y_j denote exporter and importer GDP's, P_i and P_j denote producer price indices (PPI's), d_{ij} denotes bilateral distance, and z_{ij} consists of a collection of standard bilateral gravity variables. Specification 1.1 is a direct replication of Park (2002)'s model, 1.2 slightly expands the set of gravity variables to include other standard variables such as regional trade agreements and common languages, and 1.3 expands the set of countries from fifty-one to sixty-five. As in the original paper, AVE's are inferred from the regression residuals with these models.

The second collection of models represent the alternative specifications meant to correct for the identified methodological issues. The alternative specifications follow the work of Feenstra (2002), which demonstrates that multilateral resistance can be suitably controlled for using country fixed effects within a gravity model. Fontagné et al. introduce fixed effects to the model in order to control for omitted variables and, later, use the estimated fixed effects to infer AVEs instead of using the residuals. Specifically, they estimate the model

$$\ln x_{ij} = c + 0.8 \ln y_j + \alpha_1 \ln d_{ij} + \gamma_i I_i + \gamma_j I_j + \sum_k \alpha_{ij}^k z_{ij}^k + \epsilon_{ij}. \tag{4}$$

Compared to model (3), model (4) includes the fixed effects I and treats the GDP terms slightly differently.

[6] Fontagné et al. note a third potential issue relating to the impact that the chosen elasticity of substitution has on the magnitude of AVEs. However, unlike the other two criticisms, the authors do not further address this issue and make similar assumptions.

Importer GDP y_j is constrained to have a coefficient equal to 0.8, which is based on Feenstra's specification.[7] The exporter GDP is allowed to be absorbed into the exporter fixed effect. As in model 3, they consider three specifications (2.1, 2.2, and 2.3), which differ in the same ways as the previous three specifications.

It is assumed that NTM frictions are an import-level effect and that the importer fixed effect can be used to infer the level of restrictiveness exhibited by each country.[8] As in Park (2002), free trade is not observed so that a benchmark "free trade" country must be identified. The benchmark country is assumed to be the country exhibiting the largest positive fixed effect, representing that which has the highest otherwise unexplained imports among all countries. An AVE can be computed using the relationship

$$\ln(1 + t_j)^{1-\sigma} = \gamma_j - \gamma_{benchmark}, \tag{5}$$

where the larger the difference between a country's fixed effect and the benchmark effect, the larger the inferred NTM cost and estimated AVE. The computation requires the selection of an elasticity of substitution σ, for which they use 5.6 to be comparable with Park (2002).

Comparing the two methodologies, Fontagné et al. find that Park's method systematically underestimates the level of restrictiveness at both the country and sector level. A full set of country-level AVEs are reported for the nine sectors considered, estimated from GTAP data.[9] Under the authors' preferred specification, the estimates range from 8.8 percent for government services to 98.4 percent for water transport.

A second part of the analysis addresses the other methodological concern relating to data. Fontagné et al. note that GTAP data, which had been used as a common source for services trade data, may result in erroneous estimates due to its incorporation of reconstructed data. To examine this, they also consider a second data source from the OECD that consists of a panel of countries between 2002 and 2006. This alternate data set has the benefit of being free from reconstructed observations and exhibits multiple years of observations, but is limited to only three sectors. They test the effect that the data has by comparing GTAP estimates with both an OECD cross section and an OECD panel specification. They find that there are significant differences between reconstructed GTAP data and the OECD data, suggesting that the use of reconstructed data may introduce biases, particularly among less developed economies with considerable missing data. They do not observe a notable difference between the cross section and panel approaches.

[7]Feenstra (2002) moves both GDP measures into the left hand side of the gravity equation and estimates GDP weighted trade flows. Doing so implicitly assumes a GDP coefficient of 1. Fontagné et al. (2011) follow suit, using 0.8 instead of 1 based on the argument that openness is not constant and that smaller economies are typically more open than larger ones.

[8]Importer GDPs, unlike exporter GDPs, are still controlled for so that the importer fixed effect does not reflect economic size.

[9]The nine services sectors are communications, construction, finance, insurance, (other) business services, (other) government services, trade, transport, and water transport.

2.2 Inference from NTM indices

As an alternative to inferring AVEs from unobservables within a model, much work aims to infer restrictiveness from explicit information about the NTM environments faced by traders. One such method of doing so is based on the construction of indices that reflect the restrictiveness of NTMs faced within an importing country. These indices are largely based on qualitative information gained through surveys of firms and provide relative measures of restrictiveness. This index-based methodology has emerged, in part, out of necessity given the limited data available covering the specific incidence of NTMs, relying instead on less direct measures. These indices lack the identification that may be possible if data on the actual occurrence of NTMs were available, but they still provide some identification that does not require the assumption that NTM restrictiveness can be inferred from otherwise unexplained variation.

2.2.1 Industry specific econometric modeling of NTMs: Dee (2005)

Dee (2005) studies the barriers to services industries based on restrictiveness indices derived from qualitative information. This work represents a departure from many of the previous and following studies in that it is not primarily based on gravity-based methods for quantifying NTM-related trade costs. Instead, Dee considers a collection of industry-specific, partial equilibrium models through which NTM costs are estimated. The work follows an earlier methodology described by Findlay and Warren (2000) that consists of two steps. The first step is the conversion of qualitative information about barriers to services trade into a quantitative measure. The second step uses an industry-specific econometric model to estimate the effects of those barriers on, in most cases, prices.[10]

The derivation of the restrictiveness indices are based on the conversion of qualitative information regarding barriers to quantitative metrics. For each of the seven industries considered, an index is constructed for each of a collection of industry-specific barrier categories.[11] To illustrate, for the banking sector, these categories consist of restrictions on lending; other bank business such as insurance and securities services; the expansion of branches, offices, and ATMs; and the movement of various types of employees. For each category, a score between zero and one is assigned that reflects the level of restrictiveness faced, which are then aggregated into a single index for the sector for each country. These indices are reported by industry within the paper.

The econometric models then use these indices to estimate NTM-related trade costs for each country and sector in 1997. The models differ for each sector and are generally based on prior literature studying

[10] The estimates for the telecommunications industry are a rare example of estimates derived from quantity impacts.

[11] The seven industries are air passenger transport, banking, distribution services, electricity, maritime, professional services, and telecommunications.

each specific industry. In most cases, prices are regressed against the restrictiveness index and other relevant independent variables. The estimates are then used to compare predicted prices were no measures in place with the observed prices in the presence of restrictions. The trade cost can be inferred from this price gap. The estimated AVEs are reported for each sector on a country-by-country basis. For the United States, the estimates range between 0.1 percent for financial services to 17.1 percent for legal services. While this approach has the attractive feature of being tailored specifically to each industry, it has the limitation of not being able to provide a framework that can simultaneously be applied to a wide range of industries.

Similar to Dee, Dihel and Shepherd (2007) also estimate AVEs using sector-specific econometric models that utilizes services trade restrictiveness indices (STRI). The authors create their own services trade restrictiveness indices for each of the four service supply modes (cross border trade, consumption abroad, commercial presence, and presence of natural persons) for use in the estimation of AVEs.

2.2.2 Gravity using NTM indices: Berden et al. (2009)

Berden et al. (2009) use indices reflecting NTM restrictiveness within a gravity framework in order to estimate AVEs. The work is intended to provide quantitative estimates of the regulatory divergence between the U.S. and E.U. The indices are derived from a survey conducted over firms in the U.S. and E.U. in which firms were asked about the restrictions they faced. The survey generated more than 5500 responses from twenty-three different goods and services industries. The responses were converted to measures between zero and one-hundred based on the expressed level of restrictions faced in each of many categories of NTMs, which were ultimately aggregated to the country level. These constructed indices were further cross-checked against existing indices in the literature.

The indices were then incorporated into the following gravity model

$$\ln x_{ij} = \gamma_j I_j + \gamma_i I_i - (\sigma - 1)\ln t_{ij} + \epsilon_{ij}. \tag{6}$$

Here, I denotes importer and exporter fixed effects, and t_{ij} represents an aggregate trade cost, which is decomposed into

$$\ln t_{ij} = ln(1 + \tau_{ij}) + \gamma ln N_{ij} + \sum_k \delta^k z_{ij}^k + e_{ij}. \tag{7}$$

The trade costs are composed of tariff rates τ_{ij}, the NTM indices N_{ij}, and a collection of standard gravity variables z_{ij}^k. Worth noting is that the NTM term N_{ij} is itself separated into three terms, $N_{ij} = \sum_{m=1,2,3} \gamma_m \ln(1 + I_m NTM_j))$, in which the NTM index is interacted with a dummy for joint membership in either the EEA, NAFTA, or neither (denoted by index m). This separation allows for the improved identification of the NTM effect in conjunction with regional free trade agreements.

The model is estimated for forty countries and twenty-three sectors using data from the UN, OECD, WTO, IMF, BEA, and EUROSTAT, among other sources. The estimation procedure follows a Heckman two-stage approach in which the first stage estimates the selection into trading while the second stage estimates trade values. The first stage uses a set of exogenous variables composed of distance, FDI stocks, GDP, GDP per capita, and regional trade agreement dummies. The second stage includes those detailed above in equation (6) and (7). Once estimates are constructed, AVEs can be computed using the appropriate NTM coefficient estimate according to the equation

$$\sigma ln(1+t_{ij}) = \gamma \ln(1+NTM_j). \tag{8}$$

These AVE equivalents are reported for trade between the U.S. and E.U. for the twenty-three sectors. The elasticity of substitution uses the estimated tariff coefficient for goods and a value of $\sigma = 4$ for services. The estimates for the U.S. AVEs on E.U. exports, for example, range from 2.5 percent for construction services to 73.3 percent for food and beverages.

2.2.3 Gravity with PTA depth: Egger et al. (2015)

Egger et al. (2015), like Berden et al. (2009), study NTM barriers between the U.S. and E.U., primarily in the context of the proposed Transatlantic Trade and Investment Partnership (TTIP) agreement. Egger et al. use a gravity based framework that uses information on preferential trade agreements (PTA) to proxy for NTM environments. Specifically, they develop an index that reflects the depth of PTAs between countries based on the Design of Trade Agreements (DESTA) data set (see Dür et al., 2014). PTA depth refers to the extent to which the trade agreements address and reduce non-tariff barriers to trade and may represent a reasonable proxy for the PTA induced change in the NTM environment within a trading pair. From this data, the authors assign a value between one and seven that reflects the depth of the PTA with seven representing the deepest agreement. Unlike most other methods that revolve around the estimation of NTM impacts from the presence of NTMs, Egger et al. address the issue from the alternative angle of estimating the reductions in trade costs associated with the removal NTMs. They do so for a collection of eleven categories of goods and one aggregate category.[12]

The PTA depth index is incorporated into a two stage gravity-based model. There is concern regarding potential endogeneity between trade flows and the PTA depth index, prompting the use of a control function and a first stage probit estimation.[13] In the first stage, a collection of probit models are estimated for the

[12]AVE estimates for services are presented in the paper but are collected from other sources rather than estimated.
[13]A control function is similar to an instrumental variable but offers several advantages in some cases.

selection of bilateral pairs into each of the possible values of the PTA index N_{ij} (i.e. $\delta = 1, 2, ..., 7$). The probit model, $Probit(N_{ij} = \delta | \tilde{z}_{ij}^k)$, is specified to be dependent on a collection of exogenous variables $\tilde{z}_{ij}^k$ including standard gravity variables, GDP, an index of trade embeddedness, and several constructed principal components. The results of the probit model are used to construct inverse Mills ratios $h_{\delta,ij}$ corresponding to each of the possible PTA index values. In the second stage, these ratios are used to form a control function $c(\tilde{z}_{ij}^k) = (h_{1,ij}, ..., h_{7,ij})\beta_h$ that is incorporated into the following gravity specification:

$$X_{ij} = exp(N_{ij}\beta_d + \ln(1+\tau_{ij})\beta_\tau + \sum_l z_{ij}^l \beta_z^l + \gamma_i I_i + \gamma_j I_j + c(z_{ij}^k))u_{ij}. \tag{9}$$

As before, I_j and I_i denote importer and exporter fixed effects, τ denotes tariffs, and z_{ij}^l denotes a similar collection of bilateral variables including some standard gravity variables and a measure of political distance.

The two-stages are estimated for eleven goods sectors and an aggregate goods category using cross-section data from 2011.[14] Given the results of the estimations, AVEs can be computed using the equation

$$AVE = 100 \times (e^{-bc/a} - 1). \tag{10}$$

Here, a is the ad-valorem tariff parameter, b is the NTM parameter, and c is the average value of any non-tariff trade cost (the parameter for either EU membership or a deep PTA with the EU). The calculated AVEs are reported for each of the twelve product groups for the U.S. and the E.U. AVEs for the U.S. are about 12.9 percent on average for all goods, and ranging between about 0 for primary energy and 48 percent for processed foods.

Other work has followed this type of methodology. For example, Lejárraga and Shepherd (2013) also attempt to estimate trade costs using an NTM indicator and trade agreement depth. However, they use the depth of regional trade agreements (RTAs) rather than PTAs. Similar to Egger et al. (2015), Lejárraga and Shepherd find that each additional transparency commitment in an RTA is associated with an increase in trade flows of more than one percent.

2.3 Inference from NTM incidence data

For many years, thorough data on the incidence of NTMs has been limited in both the scope of what measures are recorded as well as the countries for which data are available. Nonetheless, some research has managed to assess the impact of NTMs using data that directly indicates the presence of a measure. These methods

[14]The eleven sectors are primary agriculture, primary energy, processed foods, beverages and tobacco, petrochemicals, chemicals and pharmaceuticals, metals and fabricated metals, motor vehicles, electrical machinery, other machinery, and other manufactures. The aggregate category, is the summation of these eleven sectors.

allow for a direct estimation of the effect of NTMs and, in particular, specific types of barriers. It is likely that this type of approach will grow in popularity as the quality and coverage of NTM data improves.

2.3.1 Product-level import estimation using NTM data: Kee et al. (2009)

Kee et al. (2009) estimate AVEs of NTMs by using data on the incidence of NTMs at the product level. The methodology is similar to gravity specifications in that it uses many of the same variables used in traditional gravity modeling, such as GDP and distance to world markets. However, unlike gravity, which is bilateral, Kee et al. estimate the effect of NTMs on a unilateral basis. That is, they estimate import values dependent on a collection of trade frictions, including NTMs. The novel aspect of this work is that the authors conduct the study at the product level using similarly disaggregated data for tariffs and NTMs.

Specifically, the authors estimate the following econometric model:

$$\ln m_{ni} = \alpha_n + \delta_n C_i + \beta_{ni}^N N_{ni} + \beta_{ni}^S \ln S_{ni} + \gamma_{ni} \ln(1 + \tau_{ni}) + \epsilon_{ni} \tag{11}$$

The subscripts n and i index products and countries, respectively. α_n are product-level dummy variables that pick up product-specific effects. C_i denotes a vector of country level characteristics composed of GDP and factor endowments (agricultural land over GDP, capital over GDP, and labor over GDP). The variable N denotes the presence of a "core" NTM on product n in country i.[15] S denotes the value of agricultural domestic support in country i and τ denotes the ad valorem tariff rate. The two NTM related parameters β^k are further decomposed into $\beta_{ni}^k = \beta_n^k + \beta_n^k C_i$, which allows them to have product-level and country-level effects while maintaining a sufficient number of degrees of freedom. To restrict the NTM costs to have a negative impact on imports, as theory predicts, the coefficients are further replaced with the expression $\beta_{ni}^N = -e^{(\beta_n^N + \beta_n^N C_i)}$ (no replacement is made for the domestic support coefficients).

Kee et al. address concerns regarding the endogeneity of tariff rates by utilizing estimates for demand elasticities from Kee et al. (2008) for γ and move the whole term to the left side of the equation. Similar concerns exist for the NTM and domestic support variables and are addressed using instrumental variables. The instruments used are exports, changes in imports, and a GDP-weighted average of the NTMs present in a county's five closest neighbors. The first two instruments are common in the literature and the third, as argued by the authors, exploits observed similarities between NTM environments across neighboring countries. This variable is believed to be a valid instrument because neighboring countries are expected to impose similar NTMs based on presumed historical, legal, and cultural commonalities but the presence of NTMs in these other countries are unlikely to affect imports of the original country. Using these instruments,

[15] The term "core" NTM refers to a measure in one of the following four categories: price control measures, quantity restrictions, monopolistic measures, and technical regulations.

a two-stage Heckman procedure is used. In the first stage, a probit model is run for each product to explain the presence of an NTM or domestic support conditional on the instruments. The second stage estimates the above model using an inverse Mills ratio derived from the first stage as a control variable. For those goods in which at least one country exhibits domestic support, the second stage includes an instrumental variable estimation for domestic support.

Estimations of the above model are conducted for each of 4,575 HS6 products using data from several sources. The trade data originated from the COMTRADE data base. The tariff data were drawn from the MAcMap data base, which provides AVE estimates at the product line. The NTM data were from UNCTAD's TRAINS data base and reflects the existence of NTMs in the "core" categories. Agricultural domestic support data was derived from WTO member notifications and constructed by Hoekman et al. (2004).

The regressions provide a collection of ten coefficients that measure the impact of NTMs and domestic support on imports. These coefficients can be used to construct AVEs via the following equations:

$$AVE_{ni}^{N} = \frac{e^{\beta_{ni}^{N}} - 1}{\gamma_{ni}}, \tag{12}$$

$$AVE_{ni}^{S} = \frac{\beta_{ni}^{S}}{\gamma_{ni}}. \tag{13}$$

AVEs are reported for each country as an average across all products and across products for which there exists an NTM. For the U.S., these AVEs are 9.5 percent and 37.4 percent, respectively. In addition to the estimated AVEs, the authors use these AVEs to construct a collection of three restrictiveness indices based on earlier work by Anderson and Neary (see Anderson et al. (2005), for example). These indices are reported on a country-by-country basis for both tariffs and tariffs plus NTMs.

A number of papers have since used similar approaches, including work by Bratt et al. (2014), Beghin et al. (2015), Arita et al. (2015), and Ghodsi et al. (2016). Arita et al. (2015), for example, utilize a similar methodology that incorporates product-level NTM incidence but do so in a bilateral setting, focusing specifically on sanitary and phytosanitary measures and technical barriers to trade in several agriculture sectors.

2.3.2 Price based estimation using NTM data: Dean et al. (2009)

Dean et al. (2009) use NTM incidence data and price level data to identify price gaps resulting from the presence of an NTM. Compared to the more common volume based approaches, price gaps provide a direct measure of the associated ad valorem equivalents. Dean et al. draw on and synthesize earlier research by

Bradford (2005) and the previously discussed work by Kee et al. (2009). Dean et al. argue that Bradford (2005)'s estimates of AVEs, which are constructed from price gaps, are subject to inaccuracies stemming from the error prone measurement of CIF and FOB margins and poor consideration of product differentiation. Similarly, Dean et al. note that the work of Kee et al. (2009) suffers from similar inaccuracies due to their reliance on indirect inference through trade volumes rather than prices, an assumed Heckscher-Ohlin modeling framework, and estimated substitution elasticities. In light of these criticisms, Dean et al. (2009) propose a combination of these approaches using price data in the vein of Bradford (2005) and NTM incidence data in the vein of Kee et al. (2009).

Much of what is novel about this approach is the data that are used. For prices, the authors turn to EIU CityData that provides prices for forty-seven products (which are aggregated into four sectors) in 115 cities across sixty different countries.[16] The NTM data stems from UNCTAD's TRAINS data base as well as a firm-level survey on import restrictions conducted by the USITC.

The authors' identification strategy relies on the assumption that retail prices differ across countries for several reasons: specific tariffs, distribution markups, transportation costs, and NTM costs. Once the other differences are controlled for, the NTM effect is identified. After some averaging over product varieties within countries, an econometric model is specified:[17]

$$PG_{ij} = \beta(\mu_i - \mu_j) + \alpha(D_i - D_j) + \delta(T_i - T_j) + \sigma_0(Q_i - Q_j) + \sigma_1(Q_i\tilde{Y}_i - Q_j\tilde{Y}_j) + \sigma_2(Q_i\tilde{T}_i - Q_j\tilde{T}_j) + \gamma I_{ij} + \epsilon_{ii^*}.$$

Simply put, the price gap is a function of the markup gap (μ), the transport cost gap (D), the tariff gap (T), and the NTM gap (Q). Additionally, $\tilde{Y}$ and $\tilde{T}$ denote deviations from mean GDP and mean tariffs, respectively. In each case, the local price is compared to the average price in order to construct the gap. The price gaps are based on retail prices from CityData. The measure of local distribution markups are based on data for maid service prices (a proxy for non-traded, city-level wages), single-bedroom apartment rental rates, and GDP per capita. Transport costs are proxied for using a standard remoteness measure of export weighted distance. NTMs are assigned a dummy if either TRAINS identifies a quantity restriction or the USITC data identifies an import restriction, quota, prohibition, or import license. In their preferred specification, they include two interaction terms. First, they interact NTMs and tariffs because there is a concern that NTMs may be either substitutes or complements to tariffs. Second, they interact NTMs and GDP because there is a concern that NTMs are correlated with development such that developed countries have higher NTMs.

[16]The four sectors are fruits and vegetables, bovine meats, processed food, and apparel.
[17]Dean et al. consider several simpler variations for the model as well but ultimately arrive at this preferred specification.

The authors express concern that the NTMs exhibit endogeneity issues and consider a two-stage instrumental variable approach to correct for this. In the first stage, the incidence of NTMs are estimated conditional on tariffs, distance, GDP per capita, wages, rental rates, and export shares. The export shares, which are measured as the ratio of a country's exports in the considered sector to its total exports, functions as the instrument. The authors argue that countries are unlikely to impose NTMs on a sector that represents a relatively important export industry and likely does not experience strong import competition. Further, these export shares should not directly affect city retail prices, making them a reasonable instrument.

Under this specification, the authors estimate the above econometric model for each of the four sectors. A benefit of using a price gap based model is that the estimated parameters are themselves AVEs. Unlike in previously discussed volume based methods, the price gap based approach does not require that AVEs be backed out of the results, often using an assumed estimate for substitution elasticities. For each of the four sectors, estimated AVEs are reported on a country-by-country basis. The authors' estimates for the U.S. range between 22.6 percent for apparel to 80.0 percent for bovine meat.

Similar price gap approaches have been implemented by Rickard and Lei (2011), Nimenya et al. (2012), Arita et al. (2015) and Cadot and Gourdon (2015). Cadot and Gourdon, for example, use a panel regression to estimate the impact of product-level NTMs on consumer prices for 4,500 products in sixty countries. They find that NTMs increase the price of two-thirds of affected products and that entry into PTAs that reduce or standardize measures mitigates this effect.

3 Estimated Ad Valorem Equivalents

Table 1 contains a collection of estimated AVEs from the seven papers surveyed in the previous section. Each listed AVE represents the ad valorem trade cost associated with trade from foreign countries to the United States. The United States was chosen because it was, in these reports, the most widely included country. The numbers themselves can be interpreted as percentage changes in the trade costs resulting from the respective NTM environment in the United States.

The results are presented in a way to facilitate the cross-paper comparison of estimates where appropriate. It is important to reemphasize, however, that there are differences between the estimates in addition to the underlying methodology. In most cases, the estimates are derived from different data sources and subject to different aggregations. For example, the scope of "Financial" services in one paper may not perfectly match that in another. Similarly, the context of the AVEs themselves may differ. In particular, the estimates from Berden et al. (2009) and Egger et al. (2015) are specific to exports from the E.U. whereas in most other cases, the AVEs are averaged over all exporting countries present in the data. For this reason, it is difficult to determine the extent to which estimates differ due to the methodology employed or the data on which the estimates are based.

4 Conclusion

As interest in NTMs continues to grow, so too will the methods by which they are quantified. The papers surveyed here represent a small collection of the different approaches that authors have taken in order to estimate the trade costs associated with non-tariff measures. Each of these methods has relative strengths such as the availability of data, theoretical foundations, or easily interpreted results. Similarly, they each exhibit weaknesses such as omitted variables, indirect identification, data unavailability, and assumed supply elasticities. Given this, it is not surprising that no widely accepted methodology has arisen for the estimation of AVEs of NTMs. Future research will likely continue to make refinements to these methods and improve the accuracy of estimated trade costs. Such efforts will represent valuable contributions to economic modeling, policy analysis, and international trade research.

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Table 1: AVEs of NTM related trade costs in the United States.

Sector	Park (2002)	Fontagné et al. (2011)	Dee (2005)	Berden et al. (2009)	Egger et al. (2015)	Kee et al. (2009)	Dean et al. (2009)
Goods					12.9 to 13.7	9.5 to 37.4	
Agriculture					15.8 to 25.2		60.6 to 80.0
Manufacturing							
Aerospace				19.1			
Automotive				26.8	19.3 to 19.5		
Beverages/Tobacco					41.8 to 42.0		
Chemicals/Pharma.				9.5 to 21.0	20.6 to 29.1		
Cosmetics				32.4			
Electronics				6.5	1.7 to 19.4		
Energy					0.0 to 16.1		
Machinery					1.6 to 6.2		
Office Equipment				22.9			
Other goods					3.6 to 5.7		
Petrochemicals					7.9 to 24.2		
Processed food				73.3	33.8 to 48.4		34.6
Metals				17	16.7 to 38.5		
Textiles				16.7			22.6
Wood/Paper Prod.				7.7			
Services							
Air Transport			10.5				
Communication	7.3	36.9	6.9 to 12.1	1.7-3.9			
Construction	43.7	95.4		2.5			
Distribution			2.2				
Financial	24.6	51.3	0.1	31.7			
Professional			6.6 to 17.1				
Insurance		43.7		19.1			
Water Transport		98.4					
Other Business	41.4	42.3		3.9			
Other Government		8.8					
Pers., cult., and rec.				2.5			
Trade	52.1	61.5					
Transport	23.8	17.5					