The impact of non-tariff barriers on trade and welfare*

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Abstract

Deep trade agreements (DTAs) are widespread and have taken the world beyond tariff liberalization in goods trade. As the importance of global supply chains and the services sector has increased across the world, shallow tariff reductions have given way to deeper commitments that address non-tariff barriers and behind the border barriers to trade. This paper shows that DTA commitments undertaken since the Uruguay Round have increased trade in goods and trade in services by over half in the long term. Taking reduced-form trade elasticity estimates to a general equilibrium quantitative model, DTAs contributed over 40% to the welfare gains from trade globally and even more for advanced economies. China, India, and the Eastern European bloc benefited the most from trade agreements. While most of the gains in China and India came from tariff reductions, the gains to Eastern Europe came largely from deep commitments during its accession to the EU. Applying the DTA estimates to ex-ante analysis of Brexit, the losses to the UK from its departure from the deepest trade agreement in the world would not be offset by new deep trade deals with key non-EU trade partners.

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1 Introduction

Trade agreements, one of the most widely used policy tools for international economic integration, have evolved in volume and scope since the 1990s. Roughly 300 agreements are in force today, compared to only about 20 in 1990. Whereas the predominant focus of early trade arrangements was lowering tariffs and quantitative restrictions to ease trade in goods, modern trade agreements contain a range of deeper provisions beyond the narrow remit of traditional trade policy instruments. Such provisions are widespread across agreements and typically encompass measures such as mutual recognition of professional qualifications for service providers, investment liberalization, and intellectual property protection commitments. Trade agreements that include these provision types are often referred to as deep trade agreements (DTAs).

DTAs are widespread and have taken the world beyond tariff liberalization in goods trade. As the importance of global supply chains and the services sector increased across the world, shallow tariff reductions gave way to deeper commitments that address non-tariff barriers and behind-the-border barriers to trade. However, existing work on trade and welfare impacts of DTAs remains scant, and research on trade in services is still very limited. This paper examines the impacts of DTAs on trade and welfare, and it does so by expanding the scope to trade in services.

A first contribution of the paper is to provide reduced-form evidence that deep trade commitments increase trade, over and above shallow tariff reductions. DTAs, which include a wide range of non-tariff measures, have a stronger effect on gross exports than shallow agreements. Their trade-expansion effect is relatively larger for services than goods—signing the deepest agreement is associated with roughly a 30% boost in gross exports for services compared to just under 25% for goods.

A second contribution of the paper is to develop a structural model that builds on these reduced-form estimates to provide general equilibrium impacts of DTAs on trade and welfare. Despite a growing literature that has examined the impact of economic integration on welfare, there is limited quantitative work studying DTAs. Our approach differs from the long tradition of computable general equilibrium models to estimate the impact of trade reforms (Anderson and Martin, 2005; Cline, 2004; Hertel, 1997). Following Kehoe et al. (2017), we use a quantitative trade model (à la Caliendo and Parro, 2015; Costinot and Rodríguez-Clare, 2014) with carefully calibrated parameters and shocks from model-consistent reduced-form estimates. As such, our model enables quantification of the aggregate trade and welfare impacts of trade agreements. We focus on two major policy events for the quantification.

In the first application, we quantify the ex-post welfare gains from trade liberalization after the Uruguay Round through tariff reductions and deeper trade policy commitments. We estimate the welfare effect of trade liberalization by feeding the actual shocks in tariffs and non-tariff provisions into our model. We also identify the major winners and the primary source of their gains by separately feeding these shocks and by differentiating across sectors. A key insight is that tariff reductions in goods contributed to welfare gains prior to the EU's 2004 expansion and for the two major economies of China and India. After 2004, the contribution of DTAs to welfare gains from trade rises, and particularly for Eastern and Central European economies that became members of the world's deepest trade agreement, the European Union (EU). More broadly speaking, our analysis underscores that DTAs in developing economies are comprised of relatively few deep provisions and that this group has gained primarily from tariff reductions. On the other hand, welfare gains to industrialized economies, which actively engaged in comprehensive DTAs since the Uruguay round, come equally from deep commitments and tariff channels.

In the second application, we examine the trade and welfare impacts of Brexit, which reduces the United Kingdom's deep trade commitments with its largest trading partner but opens up new avenues for DTAs with economies outside the EU. Model simulations using the reduced-form estimates of the impact of DTAs on trade show welfare losses of roughly 1% for the UK in terms of real consumption per capita, even after accounting for a soft Brexit and deep NAFTA-type trade agreements with other potential partners like the United States. Moreover, these welfare losses from Brexit rise to more than double as policies with shallower trade agreements are considered in the counterfactual analysis. As the current trend towards deglobalization from political developments and more recently the Covid-19 pandemic continues, this application suggests that the unraveling of DTAs can undo some of the welfare gains from integration achieved in the past couple of decades.

This paper is related to three strands of the literature. First, we study DTAs in a quantitative framework, which is related to a vast evolving line of work providing general equilibrium welfare impacts of trade, as discussed in detail in subsequent sections. While the focus of quantitative trade models has largely been on tariff liberalization, more recent work has turned to examining non-tariff policy tools like rules of origin (Conconi et al., 2018), trade policy uncertainty (Steinberg, 2019), non-tariff barriers (Comerford and Rodríguez Mora, 2019) and preferential trade agreements (Felbermayr et al., 2015; Mayer et al., 2019). We build on the long tradition of work on trade agreements in gravity models (Baier and Bergstrand, 2007; for a survey of the literature see Limão, 2016), which have more recently been expanded in scope to incorporate elements of trade agreement depth (for example, Baier et al., 2017, 2014). We use a combination of reduced-form and structural modeling to answer distinct questions in this literature. Building on the enormous progress in measuring the content of DTAs through non-tariff provisions (Hofmann et al., 2017) and estimating their reduced-form trade impacts (Mattoo et al., 2017; Mulabdic et al., 2017; Orefice and Rocha, 2014), this paper quantifies the general equilibrium trade and welfare impacts of major DTAs of the past three decades.

Second, we examine services trade where deep commitments are a central trade policy tool. This connects our work to the growing body of research on services trade, such as Breinlich et al. (2018), Borchert et al. (2017), and Costa et al. (2019). Compared to these papers, we consider the impact of trade agreement provisions on services trade. Third, we quantify potential welfare impacts from deglobalization, which has been the focus of an emerging literature, such as that on the Trump tariff war, Brexit, and, more recently, the Covid-19 pandemic. While many studies have examined recent deglobalization trends, the analysis has rarely incorporated trade elasticities from DTA provisions, making it difficult to disentangle the relative contributions of shallow and deep commitments with the trade partner and the world economy (for example, Dhingra et al., 2017; HM Treasury, 2016; Kierzenkowski et al., 2016). Summing up, we build on the measurement and empirical progress on DTAs to estimate and quantify their trade and welfare impacts.

The rest of the paper is structured as follows. Section 2 describes the data sources used in our analysis and documents general trends in DTAs over time. Section 3 gives our empirical specification, which is motivated by the gravity equation literature, and presents reduced-form results. Section 4 walks through the quantitative framework used to estimate the effect of DTAs on living standards. Section 5 presents the results of two quantitative exercises: the welfare effects of trade liberalization after the formation of the WTO and the welfare effects from Brexit. Finally, Section 6 concludes.

2 Data and trends in modern trade agreements and tariffs

Our empirical analysis relies on matched data on DTAs encompassing non-tariff provisions, applied tariff rates, and bilateral exports. In what follows, we describe the data sources used and discuss trends in DTAs and bilateral tariffs over time.

Information on DTAs is drawn from the World Bank (WB) Content of Deep Trade Agreements database (herein DTA database), described in Hofmann et al. (2017). This database records information on the full set of 279 trade agreements notified to the WTO between 1958 and 2015. Importantly, it identifies 52 provision categories—each coded as a binary bilateral variable equal to unity if a given provision is present—that can exist (or co-exist) in a deep trade agreement.[1] These bilateral variables are then broken down into two broad categories: those which fall under the current WTO mandate (WTO+ provisions) and those which extend beyond the WTO mandate (WTO-X provisions). There are 14 WTO+ provisions that cover non-tariff liberalizations embedded in modern DTAs related to customs, anti-dumping, trade-related investment measures, and public procurement, among others. The remaining 38 WTO-X provisions span a wide set of policy areas ranging from competition policy, intellectual property rights, and investment to nuclear safety, energy, and human rights.

The WB further classifies these 52 provisions as “core” versus “non-core.” Core provisions are those which the literature has identified as being most relevant in terms of easing market access (see Baldwin, 2008; Damuri, 2012). These include all WTO+ provisions as well as four WTO-X areas: competition policy, investment, movement of capital, and intellectual property rights. Table 1 presents the full set of provisions in the WB DTA database, with core provisions denoted in italics.[2] A key finding from the codification is that, along with WTO+ provisions, the four core WTO-X policy areas appear most frequently in trade agreements. Almost 90% of agreements include at least one of the ”core” WTO-X provisions and one-third include all ”core” provisions”, which has motivated

[1]For example, in the WB DTA database the variable “anti-corruption” is coded as 1 if a bilateral trading pair has a DTA which covers regulations concerning criminal offense measures in matters affecting international trade and investment.

[2]See Table A1 in Hofmann et al. (2017) for a detailed description of each provisions’ definition.

the decomposition of provisions in the literature along these core and non-core features. The trade elasticity with respect to core and non-core provisions is estimated separately to account for potential heterogeneity in different provisions.

Moreover, the DTA database also relies upon expertise from legal specialists to code the enforceability of each trade agreement provision within a given bilateral agreement. A provision is classified as legally enforceable if the language used is sufficiently explicit, precise, and committing. In line with the emerging literature using this data (for example, Laget et al., 2018; Mattoo et al., 2017; Mulabdic et al., 2017), we only consider legally enforceable provisions in our baseline estimations, given that these commitments are most likely to be successfully addressed if invoked in a dispute settlement proceeding. Nonetheless, we relax this requirement when conducting robustness exercises.[3]

Table 1: WB Content of Deep Trade Agreements Database Provisions

WTO+ provisions	WTO-X provisions		
Tariffs industrial goods	Anti-corruption	Cultural cooperation	Political dialogue
Tariffs agricultural goods	*Competition policy*	Economic policy dialogue	Public administration
Customs	Environmental laws	Education and training	Regional cooperation
Export taxes	*Intellectual property rights*	Energy	Research and technology
SPS measures	*Investment*	Financial assistance	SMEs
TBT measures	Labor market regulation	Health	Social matters
State trading enterprises	*Movement of capital*	Human rights	Statistics
Anti-dumping	Consumer protection	Illegal immigration	Taxation
Countervaling measures	Data protection	Illicit drugs	Terrorism
State aid	Agriculture	Industrial cooperation	Visa and asylum
Public procurement	Approximation of legislation	Information society	
TRIMS	Audio visual	Mining	
GATS	Civil protection	Money laundering	
TRIPs	Innovation policies	Nuclear safety	

Source: Hofmann et al. (2017). *Notes:* This table lists the full set of trade agreement provisions available and included in our analysis, each of which are binary bilateral variables equal to 1 if a given country pair has a DTA with a provision in place in time t. WTO+ provisions are defined as those which fall under the current WTO mandate while WTO-X provisions are those which extend beyond the WTO mandate. Core provisions are in italics. See Table A1 in Hofmann et al. (2017) for a detailed description of each provisions' definition.

For the economies considered in our analysis, the deepest agreement is the EU agreement, which, after the 2004 expansion, is comprised of 40 legally enforceable provision categories.[4] The second deepest agreement in our sample is NAFTA, which contains 20 legally enforceable provisions. In contrast, the shallowest agreements in our sample are the China-ASEAN and India-ASEAN agreements, with 4 and 8 legally enforceable provisions, respectively.[5] For expositional purposes, Figure 1 plots the number of pairs of trade partners in our sample with a DTA, distinguishing those with less than 10 provisions, between 10 and 20 provisions, and more than 20 provisions. The jump in the number of pairs with more than 20 provisions in 2004 and 2007 is driven by EU expansions in those years.

[3]Specifically, the DTA database distinguishes between legally enforceable provisions that are explicitly excluded by dispute settlement provision and those which are not. We consider only those which are not in the category of 'excluded by dispute settlement' in our baseline analysis but examine others in a robustness exercise.

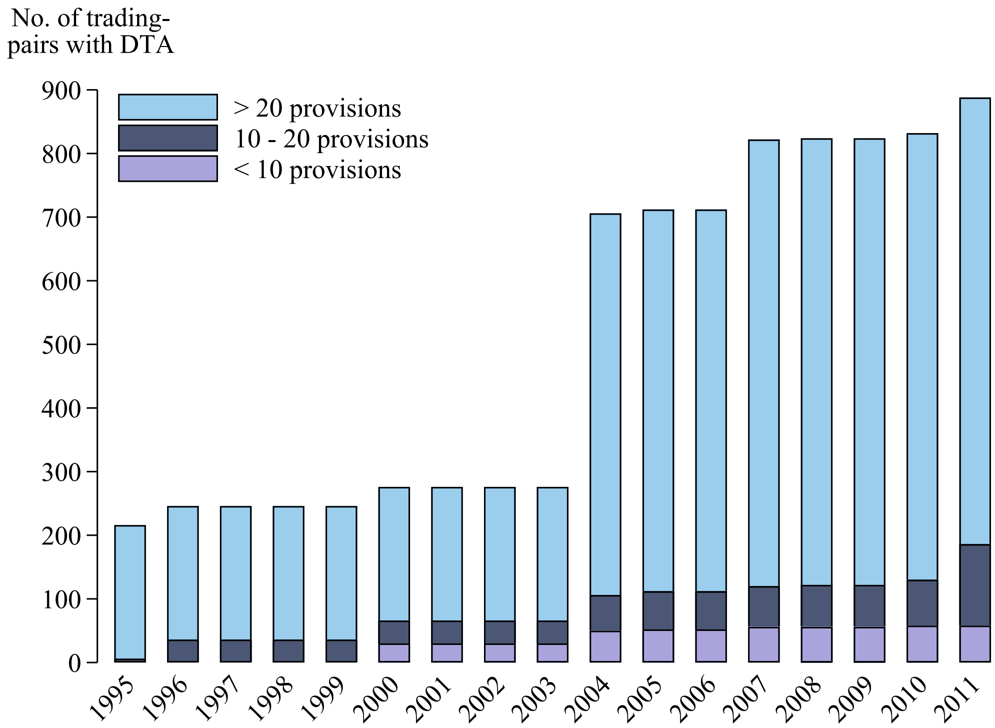
[4]Before the 2004 expansion this agreement contained 38 provisions.

[5]The only ASEAN member included individually in our trade dataset is Indonesia. All other members are accounted for in the Rest of the World aggregate.

The steady increase in agreements with 10-20 provisions represents the entry into force of agreements such as those between the US and Australia, India, and Japan, as well as the EU and Korea, among others.

Data on applied HS 6-digit bilateral tariffs that each exporter faces when sending goods to a given partner come from UNCTAD's Trade Analysis Information System (TRAINS), downloaded through the WB World Integrated Trade Solutions (WITS) platform. Three main steps are taken to clean and concord the data to the classification of our trade data (the ISIC Rev. 3). First, we construct a series of applied bilateral import tariffs at the HS 6-digit level, taking into account ad-valorem equivalents as provided by TRAINS where applicable.[6] Second, we construct the tariff faced by each exporter from each partner's respective bilateral import tariff file.[7] Finally, we aggregate HS 6-digit products to the relevant 2-digit industries of our trade data using a concordance between HS products for each HS classification year and ISIC Rev. 3 industries.[8]

Figure 1: Evolution of trade agreement depth, 1995-2011



Source: Authors' computations based WIOD and WB DTA database. *Notes:* This figure shows the number of region pairs in our sample with a DTA, decomposed into the number of legally enforceable provisions.

Figure 2 plots the average applied tariff rates imposed by each economy in our sample on all other economies in the world (aggregated across all goods sectors). The clear messages which emerge from

[6] As such, bilateral applied tariffs are constructed as the first of: preferential ad-valorem equivalent; preferential rate; MFN ad-valorem equivalent; MFN rate. In the case of Indonesia, we use the information on applied rates only due to large gaps in reporting on ad-valorem equivalents (AVEs) between 1995 and 2001.

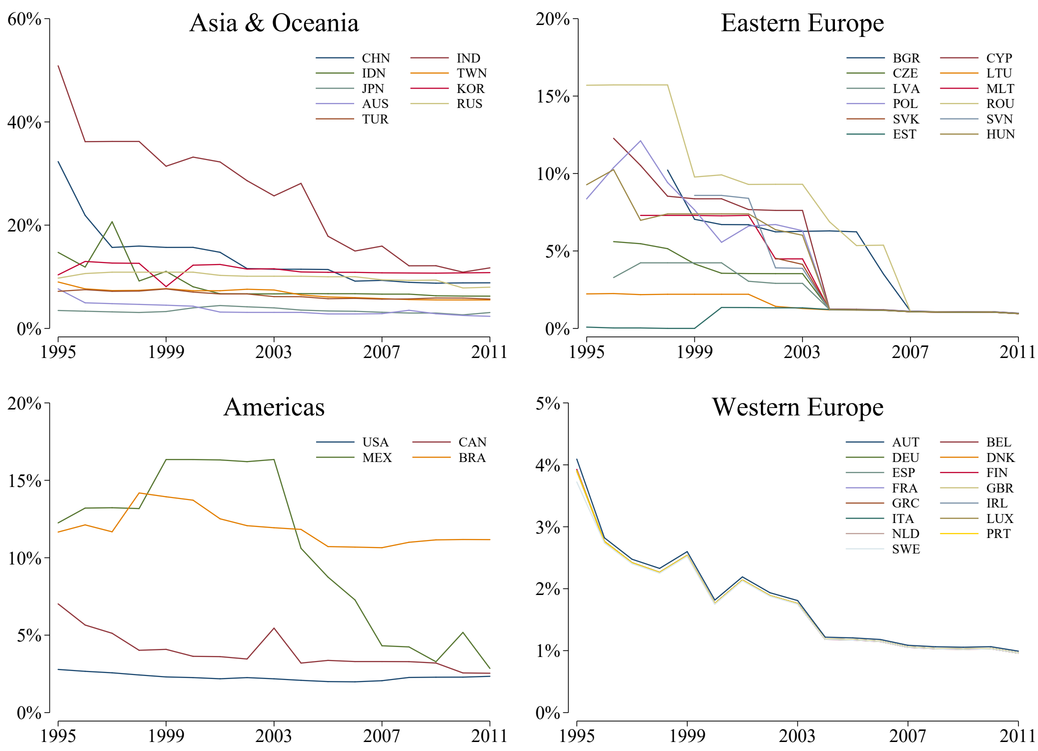
[7] For example, the tariffs faced by the United States in each respective destination to which it sends goods are simply the tariffs that each destination imposes on the US, as reported in their import tariff file.

[8] As detailed below, we source our trade data from the WIOD, which follows the ISIC Rev. 3 classification. The concordance is publicly available through the WITS platform: http://wits.worldbank.org/product_concordance.html.

the figure are threefold. First, we observe large drops in India and China's average import tariffs over the whole period. This is primarily driven by reductions in their MFN tariffs, with steady declines for India over the full period and the steepest declines for China in its lead-up to joining the WTO in 2001. Second, there is a notable drop in most Eastern European nations' average bilateral tariffs as they prepared to join the EU, albeit to differing extents. Finally, the average applied tariffs of the US and all Western European nations are relatively low during the whole period (below 5%).

Lastly, data on bilateral exports for goods and services come from the 2013 release of the World Input-Output Database (WIOD), made available by the University of Groningen and described in Timmer et al. (2015). Bilateral exports—including intra-national flows—are available for years 1995-2011 for 40 economies and a Rest of the World (RoW) aggregate. We do not work with the newer release of the WIOD because it starts in year 2000, and therefore does not cover the large integration periods after the Uruguay Round (which concluded in 1994). A particularly nice feature of the WIOD is that it covers both goods and services sectors, allowing us to examine the impact of trade agreements on trade flows at various levels of disaggregation: aggregate exports; and goods versus services exports.

Figure 2: Average applied tariff rates, 1995-2011



Source: Authors' computations based WIOD and UNCTAD TRAINS Database. *Notes:* This figure shows the average tariff rates applied by each economy in our sample to all other economies in the world. Economies are denoted following standard ISO 3-digit codes.

3 Quantifying the impact of deep trade agreements

Our welfare analysis relies, in a first stage, on the gravity 'workhorse model' of international trade. We use this to capture how bilateral exports are related to changes in the level of bilateral trade costs over time. In this section, we briefly present a gravity model, which forms the basis of our reduced-form empirical analysis.[9] We then discuss the empirical specifications implemented and present reduced-form results.

3.1 Micro-foundations of the gravity equation framework

Our reduced-form empirical model is based on the gravity equation framework summarized in Head and Mayer (2014). They define general gravity in trade flows from exporter i to importer j as the set of models that yield a bilateral trade equation (in logs) as: $lnX_{ij} = lnG + lnS_i + lnM_j + ln\phi_{ij} + \varepsilon_{ij}$ where G is a "gravitational constant," S_i represents "capabilities" of exporter i as a supplier to all destinations, M_j captures all characteristics of destination market j that promote imports from all sources, and ε_{ij} is an error term. Bilateral accessibility of importer j to exporter i is captured in $0 \leq \phi_{ij} \leq 1$, which proxies for the impact of bilateral trade costs on bilateral trade flows.

As is standard, we assume that trade costs contain both a policy-related and a natural component. Adding a time dimension t to reflect the panel nature of our dataset, the impact of trade costs on accessibility is specified as $ln\phi_{ijt} = \alpha DTA_{ijt} + \gamma ln(1 + \tau_{ijt}) + \eta_{ij}$, where DTA_{ijt} and τ_{ijt} are the policy-related components and represent any deep trade agreement variable as described in section 3.2 and bilateral export tariffs (in the case of goods exports), respectively. The use of pairwise fixed effects, η_{ij}, addresses the natural trade cost component and has been widely shown to be the most effective method to mitigate endogeneity bias between trade agreements and trade flows, as they capture time-invariant reasons for signing trade agreements such as geographical distance and common language among trade partners.

To avoid making structural assumptions on the specific forms of the origin- and destination-specific terms, the gravity equation can be estimated with exporter and importer-specific fixed effects (or, in a panel, with exporter-time and importer-time fixed effects) which subsume the region-specific terms S_{it} and M_{jt}. These fixed effects control for time-varying factors that could influence trade (such as exchange rate shocks), and they account for the multilateral resistance terms which have been theoretically and empirically shown to bias the effects of trade agreements on trade if not controlled for (Anderson and Van Wincoop, 2003; Baldwin and Taglioni, 2006).

[9] A longer discussion of the theoretical gravity model is relegated to section 4, where we discuss our quantitative model.

3.2 Empirical specification

We are interested in whether DTAs raise bilateral exports above and beyond an average trade agreement. We therefore estimate the following reduced-form equation:

$$X_{ijt} = exp\left[\alpha DTA_{ijt} + \gamma ln(1+\tau_{ijt}) + \varphi_{jt} + \delta_{it} + \eta_{ij}\right] + \varepsilon_{ijt} \quad (1)$$

where X_{ijt} represents annual bilateral imports of destination j from origin i at time t. φ_{jt} and δ_{it} are importer-time and exporter-time fixed effects, respectively, and ε_{ijt} is an error term. All other variables are as described above. We estimate equation (1) for three categories of bilateral trade flows: aggregate (i.e., goods and services sectors combined); goods sectors; and services sectors. For the case of goods, we control for (the log of) applied bilateral tariffs imposed by the importer, $ln(1+\tau_{ijt})$, specifically.[10]

We use three different measures to capture trade agreements, each of which reflects varying types of trade agreement depth. First, we proxy DTA_{ijt} in equation (1) with a dummy variable, EIA_{ijt}, equal to unity if trade partners i and j have any economic integration agreement in place at time t and zero otherwise.[11] Next, following Mattoo et al. (2017), we proxy DTA_{ijt} with two additional measures of trade agreement depth, based on the count of legally enforceable provisions (k) embedded in a given trade agreement. The first measure, $Core_{ijt} = \sum_{k=1}^{18} Provision_{kijt}$, captures the number of core provisions included in a bilateral trade agreement at any point in time. Noting that this trims down the full set of possible provisions as coded in the DTA database and thus might induce omitted variable bias, the second measure, $Depth_{ijt} = \sum_{k=1}^{52} Provision_{kijt}$, accounts for all potential trade agreement provisions. For ease of interpretation, we normalize these indices between 0 and 1, where 1 refers to the agreement with the maximum number of provisions, and 0 refers to the absence of an agreement.[12]

The literature has focused on decomposing provisions into core and non-core provisions. Given the widespread membership of the WTO, this decomposition is economically meaningful because it provides a benchmark for provisions that are available through the multilateral trading system. Another approach would have been to estimate the trade elasticity for each provision separately. Identifying the effect of individual DTA provision categories however is not feasible using traditional gravity methods because trade agreements typically feature a number of provisions so there is a dimensionality problem. Importantly, clusters of provisions appear in different trade agreements together, so there is also a multicollinearity problem which makes interpretation of individual coefficients less plausible. As a result, we focus on core and non-core provisions in our baseline estimation and examine heterogeneity with respect to legal enforceability of provisions afterwards. A growing literature has emphasized

[10]Note that controlling for tariffs on trade in services is not applicable as bilateral tariffs only apply to goods which physically cross borders.

[11]For the economies covered in our sample, the relevant EIA types are free trade agreements or customs unions.

[12]In the case of $Core_{ijt}$ the maximum number of provisions is 18. In the case of $Depth_{ijt}$—for our sample at hand—the maximum number of provisions is 40.

the importance of dispute settlement in trade agreements and we examine heterogeneity along this dimension in robustness exercises (Maggi and Staiger, 2011).

In our sample, certain trade agreements, such as the EU agreement, become deeper over time by introducing additional provisions. The main sources of variation thus come from the entry into force of a new DTA and adding provisions to pre-existing trade agreements. In equation (1), the estimated coefficient of interest is α, which gives the extent to which DTAs raise bilateral trade flows, holding economy-wide outcomes fixed. In line with the latest techniques in the literature, we apply the Poisson pseudo maximum-likelihood (PPML) estimation technique proposed by Santos Silva and Tenreyro (2006, 2011) as a way to account for the presence of zero trade flows between bilateral partners, as well as to control for potential heteroskedasticity in our trade data.[13]

Finally, we estimate our baseline specification using annual data. Annual data enables a mapping of our reduced-form estimates to annual frequency data in the quantitative model, keeping the two components of the analysis consistent with each other. Further, the use of annual data has been shown to lead to more precisely estimated gravity coefficients (Egger et al., 2022). Relative to most gravity model studies that consider trade in goods starting in the 1960s, the WIOD provides greater disaggregation between goods and services sectors at the expense of a relatively short (16 year) panel. Thus, proceeding with annual data allows us to retain a maximum amount of observations for each export category.[14]

3.3 Reduced-form results

Table 2 presents the results of equation (1) for aggregate, goods, and services exports.[15] Three main observations are noteworthy. First, the magnitude of the trade agreement variable at hand increases with agreement depth, irrespective of the type of trade flow in question. This pattern of increasing magnitude across depth variables confirms results from Mattoo et al. (2017).[16]

Second, comparing results from columns 2a-2c with results from columns 3a-3c suggests that the effect of DTAs is larger for trade in services than trade in goods. This result—which is not well documented in the literature—provides evidence that DTAs that include substantive non-tariff provisions play an important role in services trade overall.[17] It shows that services exports respond more to DTAs but it does not decompose whether this is driven by deeper commitments being undertaken in services sectors or by larger trade elasticities in services.

Third, while the overall effect of DTAs is relatively larger for trade in services, our results also

[13]We implement these regressions in Stata using the regression command `ppmlhdfe` by Correia et al. (2019).

[14]Using annual versus interval data—and the appropriate length of intervals—is a widely discussed issue in the gravity literature. We address this through robustness exercises, whereby we re-estimate our empirical specifications using 2-year and 4-year interval data.

[15]In all reduced-form specifications presented, we exclude the RoW aggregate as it contains some economies with which economies in our sample have an agreement. Nonetheless, including the RoW aggregate only changes results trivially.

[16]Mattoo et al. (2017) find an even larger (and, as they note, somewhat puzzling) jump in magnitude between $Core_{ijt}$ and $Depth_{ijt}$.

[17]Looking at global value chain trade, Laget et al. (2018) find that the impact of DTAs is typically higher for value-added trade in services compared to value-added trade in goods.

suggest that such agreements positively impact goods exports, even after controlling for bilateral tariffs. This is seen by comparing column 2c with column 2a. This again supports the role of non-tariff provisions in fostering deeper trade links which engender bilateral goods exports in a meaningful way, beyond the pure reduction of tariffs.

Table 2: Contemporaneous agreement effects

	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)	(3a)	(3b)	(3c)
	Aggregate Exports			Goods Exports			Services Exports		
	$EIA_{ij,t}$	$Core_{ij,t}$	$Depth_{ij,t}$	$EIA_{ij,t}$	$Core_{ij,t}$	$Depth_{ij,t}$	$EIA_{ij,t}$	$Core_{ij,t}$	$Depth_{ij,t}$
$DTA_{ij,t}$	0.094**	0.112**	0.138***	0.123**	0.180***	0.221***	0.183***	0.237***	0.259***
	(0.041)	(0.044)	(0.043)	(0.050)	(0.057)	(0.056)	(0.034)	(0.037)	(0.039)
$ln(1+\tau_{ij,t})$	-0.230***	-0.229***	-0.226***	-0.272***	-0.265***	-0.261***			
	(0.038)	(0.038)	(0.037)	(0.039)	(0.038)	(0.037)			
FEs (it, jt, ij)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	27,191	27,191	27,191	26,434	26,434	26,434	27,200	27,200	27,200

Notes: This table shows the estimation results for equation (1) for aggregate gross exports, goods exports, and services exports. Data is for years 1995-2011 (annual). RoW aggregate excluded. SEs clustered by ij-pair are in parentheses. *, **, and *** denote statistical significance at the 10, 5, and 1% levels, respectively.

3.4 Reduced-form robustness

We examine the robustness of the baseline results in terms of heterogeneity of provisions and timing of impacts.

Heterogeneity of provisions—A large theoretical literature examines the impacts of different dispute settlement mechanisms on exports. We relax the requirement that legally enforceable provisions must include dispute settlement, thus expanding the number of underlying provisions included in both $Core_{ij,t}$ and $Depth_{ij,t}$. This also allows us to explore an additional margin of heterogeneity of agreement depth, by effectively accounting for additional provision categories which are excluded from our baseline depth measures. Results corresponding to equation (1) are presented in Appendix Table A1 and results corresponding to equation (2) are presented in Appendix Table A2. In both tables, the variables $CoreAll_{ij,t}$ and $DepthAll_{ij,t}$ now refer to the expanded set of provisions. We find that results are similar and the trends described above hold.

Timing of Analysis—One concern in the literature has been that variability of trade flows in annual data and the path of adjustment of economic agents to the trade agreements. To examine these, we start with pooling our data over two-year and four-year intervals. This is motivated by the argument that using interval data in gravity specifications is the best approach to isolate results from year to year variability and to account for the fact that trade agreement effects might not adjust in a single year's time (see Yotov et al., 2016 for a thorough discussion).[18] Our main results continue to hold when using data over two- or four-year intervals, as shown in Table A3. Overall we observe the same trends, while the magnitude of our point estimates increases slightly with larger intervals. As such, we posit that if anything, our main results provide a lower bound of the overall effect of DTAs.

[18] The literature cited typically uses panel data for long time periods over four-year or five-year intervals (e.g. Anderson and Yotov, 2016; Baier and Bergstrand, 2007; Baier et al., 2014).

Using annual versus interval data in gravity estimation—and the appropriate length of intervals—is a widely discussed issue in the gravity literature (Yotov et al., 2016). In particular, because the adjustment of trade flows in response to trade policy changes will not be instantaneous, researchers have often used panel data with three- to five-year intervals instead of data pooled over consecutive years.[19] More recently, however, Egger et al. (2022) convincingly argue that, relative to using interval data, the use of consecutive-year data and an event window is preferable for two main reasons. On the one hand, it avoids downward-biased estimates of trade policy changes during an event window due to anticipation and maturation effects. On the other, it improves the efficiency of effect estimates by retaining the maximum amount of data. This latter consideration is particularly important in our setting, as the WIOD provides greater disaggregation between goods and services sectors at the expense of a relatively short (16 year) panel.

Timing of DTAs and their impacts—Another concern is that equation (1) estimates the contemporaneous effect of DTAs on bilateral trade flows and does not distinguish between the short-run and long-run effects of trade to the entry into force of a trade agreement. As such, we further refine specification (1) by allowing for multiple years of adjustment. This is important, as it is well known that trade responds gradually to changes in trade barriers, both in terms of anticipation effects as agreements are typically announced before they enter into force and phase-in effects as adjustments take place over an extended time period after an agreement is implemented (Egger et al., 2022). Accordingly, we specify the following reduced-form equation:

$$\begin{aligned} X_{ij,t} &= \exp\left[\sum_{a=1}^{3}\alpha_a DTA_{ij,t+a} + \alpha DTA_{ij,t} + \sum_{m=1}^{3}\alpha_m DTA_{ij,t-m} + \sum_{a=1}^{3}\gamma_a ln(1+\tau_{ij,t+a})\right] \\ &\quad \times \exp\left[\gamma ln(1+\tau_{ij,t}) + \sum_{m=1}^{3}\gamma_m ln(1+\tau_{ij,t-m}) + \varphi_{jt} + \delta_{it} + \eta_{ij}\right] + \varepsilon_{ijt} \end{aligned} \tag{2}$$

Equation (2) is similar to equation (1), however we now include three years of annual leads to capture anticipation ("a") effects and and three years of annual lags to capture maturation ("m") effects of any given trade agreement. As such, specification (2) covers seven years of possible adjustment to a new bilateral trading arrangement.

Egger et al. (2022) experiment with different ways of treating the data. In one type of analysis, they use data from every t'th year where $t = \{5, 4\}$ to form intervals. In another, they examine averaging trade flow data over 5-year and 4-year intervals. Importantly, results of their total agreement effect when using interval and averaged data in conjunction with leads and lags are close to those when using consecutive-year data and an event window. Thus, they advocate for the type of specification we employ in equation (2) which takes advantage of all available data.[20]

[19] See Trefler (2004) for three-year intervals, Anderson and Yotov (2016) for four-year intervals, and Baier and Bergstrand (2007) for five-year intervals.

[20] In a robustness exercise, we re-estimate equation (1), i.e. without leads and lags, using two-year and four-year interval data. Given the shorter time period in our analysis relative to theirs, these specifications drop more observations and we therefore focus on equation (2) for our main results.

As with equation (1), we estimate equation (2) for aggregate, goods, and services exports. For the case of goods, when controlling for the log of applied bilateral tariffs imposed by the importer, $ln(1 + \tau_{ijt})$, we also allow for anticipation and maturation effects for tariffs.

In equation (2), the estimated coefficients of interest are the α terms, which we aggregate into an anticipation, maturation, and total effect. We specify the anticipation effect as per equation (2), i.e. $\sum_{a=1}^{3} \alpha_a DTA_{ij,t+a}$, where, informed by the literature on anticipation of trade agreements, we allow for three years of annual anticipation prior to the entry into force of an agreement. We define the total maturation effect of an agreement as the combination of the contemporaneous agreement effect and annual three-year lags, i.e. $\alpha + \sum_{m=1}^{3} \alpha_m DTA_{ij,t-m}$. As such, the maturation effect encompasses both the entry into force of an agreement and its phase-in over time. Finally, the total (long-run) effect is defined as the sum of the anticipation and maturation effects.[21] Importantly, these point estimates give the extent to which DTAs raise bilateral trade flows over both the short- and the long-run, holding economy-wide outcomes fixed.

We next present results of equation (2) for aggregate, goods, and services exports in Table 3. For brevity, we present the accumulation, maturation, and total agreement effects for each agreement category, and relegate full results to Appendix Table A4. In line with results presented in Table 2, we also note that the magnitude of the trade agreement variable at hand increases with agreement depth, irrespective of the type of trade flow in question. More specifically, looking at the total effect of an agreement, the point estimate on $EIA_{ij,t}$, which captures the average total effect of any bilateral agreement irrespective of the number of provisions, suggests that bilateral exports between partners that sign an agreement increase by 30.5% (column 1a for aggregate exports). This is lower than the overall impact of signing an agreement with the highest depth for $Core_{ij,t}$ (35.5%, column 1b) and $Depth_{ij,t}$ (39.7%, column 1c).[22]

From a policy standpoint, our results thus provide empirical backing to the notion that DTAs, which include a wide range of non-tariff provisions, have a stronger effect on exports than shallow agreements, given their ability to address behind-the-border trade barriers in addition to the reduction of tariffs. Moreover, our results underscore that provisions which might seem less direct as trade policy instruments (such as clauses on education and training or health) do in fact play a role as non-tariff measures.

Second, and again similar to patterns which emerged in Table 2, comparing results from columns 2a-2c with results from columns 3a-3c suggests that the effect of DTAs is larger for trade in services

[21] The literature typically points to the fact that the duration of the trade response adjustment period to a new agreement is roughly 5 to 10 years (Baier and Bergstrand, 2007; Egger et al., 2022). Given the relatively short time dimension of our trade data, we limit the adjustment period to seven years.

[22] The overall percentage change in exports resulting from EIA_{ijt} (a dummy variable equal to zero in the absence of an agreement and one otherwise) is calculated as $100 * [exp(\hat{\alpha}) - 1]$, where $\hat{\alpha}$ is the parameter estimate on EIA_{ijt}. Because both depth variables, $Core_{ijt}$ and $Depth_{ijt}$, are normalized between 0 and 1 (where a value of 1 refers to an agreement with the maximum number of provisions), following Mattoo et al. (2017) we interpret point estimates on these variables by looking at the change in expected trade when the normalized depth variable goes from 0 to 1. Similarly to above, this is calculated as $100 * [exp(\hat{\alpha}) - 1]$, where $\hat{\alpha}$ is now the parameter estimate on the depth variable in question and hence the effects discussed relate to signing the deepest agreement.

than trade in goods. The total agreement estimate on $Depth_{ij,t}$ in column 3c suggests that trade in services between partners that sign an agreement with the highest depth increases by 60.3%, versus 52.5% for trade in goods (column 2c).

In terms of goods exports, results of the long-run specification (2) also suggest that such agreements positively impact goods exports, even after controlling for bilateral tariffs. This is seen in column 2c, where the total agreement point estimate on $Depth_{ij,t}$ indicates that trade in goods between partners that sign an agreement with the highest depth increases by 52.5% (versus 35.7% when examining the point estimate on $EIA_{ij,t}$ in column 2a).

Interestingly, results presented in Table 3 also suggest that the strongest tariff effects take place during the maturation phase of a given preferential trading arrangement. Unpacking this further, in Appendix Table A4 we note that these effects are most prevalent upon the entry into force of an agreement and do not get amplified further over time.

Finally, when looking at rows (1) and (2) of Table 3 we note that total anticipation and maturation effects within each agreement and trade flow type are broadly similar. This speaks to the importance of examining the full path to adjustment of trade agreements, and provides additional evidence that trade responds gradually to positive changes in trade barriers both in anticipation of and after the entry into force of an agreement. Importantly, comparing results from row 1 with the total long-run DTA effect (rows 1 + 2) indicates that both the short- and long-run effects of trade agreements are non-trivial.

Table 3: Anticipation, maturation, and total effects

	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)	(3a)	(3b)	(3c)
	Aggregate Exports			Goods Exports			Services Exports		
	$EIA_{ij,t}$	$Core_{ij,t}$	$Depth_{ij,t}$	$EIA_{ij,t}$	$Core_{ij,t}$	$Depth_{ij,t}$	$EIA_{ij,t}$	$Core_{ij,t}$	$Depth_{ij,t}$
(1): $\sum_{a=1}^{3} \alpha_a DTA_{ij,t+a}$	0.144***	0.150***	0.174***	0.145***	0.178***	0.212***	0.156***	0.196***	0.216***
	(0.042)	(0.043)	(0.040)	(0.055)	(0.057)	(0.053)	(0.041)	(0.041)	(0.039)
(2): $\alpha + \sum_{m=1}^{3} \alpha_m DTA_{ij,t-m}$	0.122***	0.154***	0.160***	0.160***	0.205***	0.209***	0.189***	0.249***	0.256***
	(0.045)	(0.047)	(0.047)	(0.050)	(0.053)	(0.053)	(0.051)	(0.055)	(0.056)
Total DTA effect= (1) + (2)	0.266***	0.304***	0.334***	0.305***	0.383***	0.422***	0.345***	0.445***	0.472***
	(0.065)	(0.066)	(0.063)	(0.083)	(0.088)	(0.084)	(0.045)	(0.051)	(0.054)
(3): $\sum_{a=1}^{3} \gamma_a ln(1+\tau_{ij,t+a})$	0.030	0.022	0.020	-0.024	-0.032	-0.036			
	(0.042)	(0.042)	(0.043)	(0.049)	(0.048)	(0.048)			
(4): $\gamma + \sum_{m=1}^{3} \gamma_m ln(1+\tau_{ij,t-m})$	-0.165***	-0.156***	-0.155***	-0.134***	-0.120***	-0.116***			
	(0.050)	(0.050)	(0.051)	(0.044)	(0.044)	(0.044)			
Total tariff effect = (3) + (4)	-0.135**	-0.134***	-0.134***	-0.158***	-0.153***	-0.153***			
	(0.053)	(0.052)	(0.051)	(0.058)	(0.057)	(0.056)			
FEs (*it*, *jt*, *ij*)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17,588	17,588	17,588	16,831	16,831	16,831	17,600	17,600	17,600

Notes: This table shows the estimation results for equation (2) for aggregate gross exports, goods exports, and services exports. Data is for years 1995-2011 (annual). RoW aggregate excluded. SEs clustered by *ij*-pair are in parentheses. *, **, and *** denote statistical significance at the 10, 5, and 1% levels, respectively.

4 Quantitative framework

To estimate the welfare effect of DTAs, we use a quantitative trade model of the global economy, which generates a gravity equation for trade flows and provides a mapping from trade to welfare gains. We follow Costinot and Rodríguez-Clare (2014) and Caliendo and Parro (2015) to set up a general equilibrium multi-sector model with trade in intermediate inputs and input-output linkages. Arkolakis et al. (2012) show that many workhorse trade models deliver the same predictions of "gains from trade." More importantly, these models enable the "hat algebra approach" (Dekle et al., 2008) which provides a mapping of the data to the model and allows us to perform counterfactual trade policy simulations with relatively few requirements for the estimation of model parameters.

We contribute to this literature by introducing two important differences in our approach, as compared to Costinot and Rodríguez-Clare (2014). First, while they focus on hypothetical shocks to tariffs and non-tariff barriers, we examine the welfare effects of actual changes in observed tariffs and non-tariff provisions in DTAs since the Uruguay Round. Otherwise stated, we use reduced form estimates of the impact of observed tariffs and DTA provisions to inform which shocks to feed into our quantitative model. Second, juxtaposing this information with 1995 levels allows us to estimate a series of welfare changes due to trade liberalization across our whole sample period.[23]

In what follows, we first present our multi-sector model with trade in intermediate inputs and input-output linkages. We apply the "hat algebra approach" to such a model and then describe our model-based accounting approach to simulate the welfare effect of DTAs.

4.1 Model

Demand Side—Suppose there are N countries, indexed by $j = 1, ..., N$, and S sectors, indexed by $s = 1, ..., S$. In each country, the representative household maximizes the following two-tier utility:

$$u_i = \prod_{s=1}^{S} C_{i,s}^{\beta_{i,s}}, \tag{3}$$

while $\beta_{i,s}$ is the Cobb-Douglas expenditure share of sector s in country i satisfying $\sum_s \beta_{i,s} = 1$, and $C_{i,s}$ is total consumption of composite good s given by a CES aggregator:

$$C_{i,s} = \left(\int_{\omega \in \Omega_{is}} c_{i,s}(\omega)^{(\sigma_s - 1)/\sigma_s} d\omega \right)^{\sigma_s/(\sigma_s - 1)}, \tag{4}$$

where $\sigma_s > 1$ is the sector-specific elasticity of substitution and Ω_{is} is the set of available differentiated good variety.

Production and Trade—Suppose each country is endowed with a measure L_i unit of labor. The

[23]Our model does not capture trade dynamics, but it does use observed tariff and DTA changes in each year to examine welfare changes over a 16-year time span. For trade dynamics, see Alessandria and Choi (2014), Alessandria et al. (2021), Boehm et al. (2020), Caliendo et al. (2019), and Khan and Khederlarian (2021).

production of final goods variety requires both labor inputs and composite intermediate goods. To be specific, we assume that the unit cost function of a variety ω of sector s in country i is given by:

$$c_{i,s} = w_i^{\alpha_{i,s}} \prod_{n=1}^{S} P_{i,n}^{\alpha_{i,ns}}, \tag{5}$$

where w_i is the wage rate of labor in country i, $\alpha_{i,s}$ is the share of labor inputs, $\alpha_{i,ns}$ are the sectoral intermediate input expenditure shares such that $\alpha_{i,s} + \sum_{n=1}^{S} \alpha_{i,ns} = 1$, and $P_{i,n}$ is the price of the composite intermediate inputs given by:

$$P_{i,n} = (\sum_{j=1}^{N} P_{ji,n}^{1-\sigma_n})^{\frac{1}{1-\sigma_n}}, \tag{6}$$

where $P_{ji,n}$ is the price index of intermediate good n sourced from country j.

Trade is costly. To deliver one unit of goods from i to j, $d_{ij,s} \geq 1$ units have to be shipped. Therefore, $d_{ij,s}$ represents iceberg trade costs (Samuelson, 1954) which capture all non-tariff barriers of trade, which are shaped by DTAs. In addition, there are tariffs imposed by governments on foreign imports. The *ad-valorem* tariff rate imposed by country j on good s from country i is $\tau_{ij,s}$. Taking both non-tariff barriers and tariffs into account, and under the assumption that markets are perfectly competitive, the price index of intermediate goods in country j sector s sourced from country i is given by:

$$P_{ij,s} = d_{ij,s}(1 + \tau_{ij,s})c_{i,s}. \tag{7}$$

Trade flows include both final and intermediate goods. Under our assumption that they share the same CES elasticity, the aggregate trade flow follows the gravity equation such that

$$X_{ij,s} = \frac{P_{ij,s}^{1-\sigma_s}}{P_{j,s}^{1-\sigma_s}} E_{j,s}, \tag{8}$$

where $E_{j,s}$ is the total expenditure of country j on goods in sector s, which we specify below. Therefore, the expenditure share on goods in sector s produced by country i is given by:

$$\lambda_{ij,s} \equiv \frac{X_{ij,s}}{E_{j,s}} = \frac{P_{ij,s}^{1-\sigma_s}}{P_{j,s}^{1-\sigma_s}}. \tag{9}$$

Trade Balance and Total Expenditure—Due to the Cobb-Douglas preference, without trade in intermediate goods and input-output linkages, sectoral expenditure is simply $E_{j,s} = \beta_{j,s}(Y_j + T_j + D_j)$, where $Y_j = w_i L_j$ is total factor income, T_j is total tariff revenues, and D_j is the exogenous aggregate trade imbalance. [24] With input-output linkages, sectoral expenditure is given by:

$$E_{j,s} = \beta_{j,s}(Y_j + T_j + D_j) + \sum_{n=1}^{S} \alpha_{j,sn} R_{j,n}, \tag{10}$$

where $T_j = \sum_{i=1,s=1}^{N,S} \frac{\tau_{ij,s}}{1+\tau_{ij,s}} X_{ij,s}$ is the aggregate tariff revenue, $R_{j,n} = \sum_{i=1}^{N} \frac{X_{ji,n}}{1+\tau_{ji,n}}$ is the sectoral revenue, and $Y_j = \sum_{s=1}^{S} \alpha_{i,s} R_{j,s}$ is the aggregate labor income.

Competitive Equilibrium—Given the preference parameters ($\beta_{i,s}$, σ_s), technology parameters ($\alpha_{i,s}, \alpha_{i,ns}$), trade deficits ($D_j$), tariffs ($\tau_{ij,s}$) and non-tariff barriers ($d_{ij,s}$), the competitive equilibrium is determined by equations (5)-(10).

4.2 Hat Algebra and Welfare

In general, to simulate the welfare impact of any trade policy reform requires solving the system of equations (5)-(10). But this would rely on knowing the level of all model primitives, which might be difficult to estimate. We instead adopt the "Hat Algebra" approach (Dekle et al., 2008). This approach solves the model in terms of changes, thus eliminating the need to incorporate information on the full set of parameters discussed above. Defining $\widehat{x} = x'/x$, where x' is the level of x after a (trade policy) shock, we can rewrite equations (5)-(10) as follows:

$$\widehat{c}_{i,s} = \widehat{w}_i^{\alpha_{i,s}} \prod_{n=1}^{S} \widehat{P}_{i,n}^{\alpha_{i,ns}}, \tag{11}$$

$$\widehat{P}_{i,n} = (\sum_{j=1}^{N} \widehat{P}_{ji,n}^{1-\sigma_n} \lambda_{ji,n})^{\frac{1}{1-\sigma_n}}, \tag{12}$$

$$\widehat{P}_{ij,s} = \widehat{d}_{ij,s} \frac{1+\tau'_{ij,s}}{1+\tau_{ij,s}} \widehat{c}_{i,s}, \tag{13}$$

$$\widehat{\lambda}_{ij,n} = \frac{\widehat{P}_{ij,n}^{1-\sigma_n}}{\sum_{k=1}^{N} \widehat{P}_{kj,n}^{1-\sigma_n} \lambda_{kj,n}}, \tag{14}$$

$$\widehat{E}_{j,s} E_{j,s} = \frac{\beta_{j,s}}{1 - \sum_{i=1,s=1}^{N,S} \frac{\tau'_{ijs}}{1+\tau'_{ijs}} \widehat{\lambda}_{ij,n} \lambda_{ij,n} \beta_{j,s}} (Y'_j + D'_j + T'_j) + \sum_{n=1}^{S} \alpha_{j,sn} R'_{j,n}, \tag{15}$$

where $Y'_j = \sum_{s=1}^{S} \alpha_{i,s} R'_{j,s}$, $R'_{j,s} = \sum_{k=1}^{N} \frac{\widehat{\lambda}_{kj,s} \lambda_{kj,s}}{1+\tau'_{kj,s}} \widehat{E}_{k,s} E_{k,s}$, and $T'_j = \sum_{i=1,s=1}^{N,S} \frac{\tau'_{ij,s}}{1+\tau'_{ij,s}} \widehat{\lambda}_{ij,s} \lambda_{ij,s} \widehat{E}_{j,s} E_{j,s}$.

According to equations (11)-(15), given the preference and technological parameters and shocks on tariffs ($\tau_{ij,s} \rightarrow \tau'_{ij,s}$), non-tariff barriers ($d_{ij,s} \rightarrow d'_{ij,s}$), or trade imbalances ($D_j \rightarrow D'_j$), we only need

[24] Endogenizing trade imbalances requires to model the aggregate saving and investment decision of a given agent (Dix-Carneiro et al., 2021). To keep our model simple, we take trade imbalance as exogenously given in our model. We also follow Costinot and Rodríguez-Clare (2014) to remove the trade imbalances from the data and conduct the counterfactual analysis in a model with balanced trade. Nevertheless, the results are quantitatively close to our baseline results without removing trade imbalances from the data.

to observe the status quo trade share $\{\lambda_{ij,s}\}$, $i,j=1,...,N; s=1,...,S$ to solve the model in terms of changes. Given the preference specified in Equation (3), the changes in consumer welfare can be evaluated by changes in real consumption:

$$\widehat{u}_j = \widehat{c}_j = \frac{\widehat{Y_j + D_j + T_j}}{\widehat{P_j}}, \tag{16}$$

where $\widehat{Y_j + D_j + T_j}$ is the change in total income and $\widehat{P}_j = \prod_{i=1,s=1}^{N,S} \widehat{P}_{i,s}^{\beta_{j,s}}$.[25]

Adopting the method above, we can compute the change in real consumption for any period t relative to a benchmark period, $\widehat{c}_{jt}$. To account for the impact of a trade policy reform that makes bilateral trade costs (including tariff and non-tariff barriers) evolve over time, we need to evaluate the discounted value of real consumption flows. To do so, we assume that the representative household has a lifetime utility function given by:

$$U_j = \sum_{t=0}^{\infty} \beta^t \ln(u_{jt}),$$

where u_{jt} has the same specification as equation (3), and $\beta \in (0,1)$ is the discount factor. We measure the welfare impact of a trade policy reform in terms of equivalent variations. To be specific, it is the permanent proportional change in real consumption that would keep the household's lifetime utility the same with or without the trade policy reform. Suppose $\{c_{jt}\}_{t=0}^{\infty}$ and $\{c'_{jt}\}_{t=0}^{\infty}$ are the real consumption flows with and without the trade policy reform, respectively, and that Δ_j, the consumption equivalent of country j, is defined as:

$$\sum_{t=0}^{\infty} \beta^t \ln(\Delta_j \cdot c_{jt}) = \sum_{t=0}^{\infty} \beta^t \ln(c'_{jt}).$$

Then, the consumption equivalent Δ_j satisfies:

$$\ln(\Delta_j) = (1-\beta) \sum_{t=0}^{\infty} \beta^t \ln(\widehat{c}_{jt}), \tag{17}$$

while $\widehat{c}_{jt} \equiv c'_{jt}/c_{jt}$ is the counterfactual change in real consumption, which we can estimate using the hat algebra approach for each period.

As the model is static, it quantifies the long-run effects of DTAs. In other words, it does not seek to explain the drivers of short-run adjustment and focuses on the overall effects of DTAs.

5 Quantitative Results

We use the model described above and data from the WIOD to simulate the welfare effect of two major changes in trade policy. Following Costinot and Rodríguez-Clare (2014), the WIOD data is

[25] We follow Costinot and Rodríguez-Clare (2014) to normalize the world GDP to one.

aggregated to 31 regions and 31 sectors.[26] Data on sectoral and regional output expenditure shares and the share of intermediate inputs sourced from each other in production are taken from the WIOD. Trade elasticities are from estimates provided in Caliendo and Parro (2015).[27]

We examine two major trade policy changes. First, we estimate the ex-post welfare gains which ensued from widespread trade liberalization that took place following the conclusion of the Uruguay Round and the formation of the WTO in 1995. Following historical developments in the world trade landscape, the years 1995-2011 saw a rapid decline in tariff barriers, the signature of several DTAs, and the deepening of some pre-existing trade agreements.

Second, we use our framework to simulate welfare changes following Brexit under different policy scenarios of DTAs with the EU and with economies outside the EU. The UK's departure from the EU is the largest DTA reversal in recent history. Brexit is a fracture in the world's deepest trade agreement and arises in a setting where services trade and deep commitments are key components of aggregate economic impacts. While a number of studies have examined its tariff implications, an understanding of non-tariff barriers, particularly in the services sector, is less well-understood. The reduced form deep trade agreement estimates and the structural model provide new results for the evolution and deepening of UK's trade relationships within and outside the EU.

5.1 Trade liberalization after the WTO is formed: 1995-2011

The conclusion of the Uruguay Round of the WTO presents a landmark event for the multilateral trading system. Yet there are few studies that quantify the impacts of the trade liberalisation—from the tariff reductions and the deep commitments—that was undertaken under the World Trade Organisation. This is highlighted in Figures 1 and 2, which show an uptick in DTAs and a considerable decline in applied tariff rates, respectively. Two notable developments that occurred in the world trading system after the Uruguay Round were the expansion of the largest customs union in the world, the EU, and large tariff reductions by two of the largest developing economies, China and India.

How much did the world benefit from this round of trade liberalization? We answer this question by feeding estimated changes in DTAs and observed tariff reductions into our quantitative trade model. We proceed as follows. We first consider the estimation result from the contemporaneous effect specification. Setting year 1995 as the base year, we infer the change in non-tariff barriers of trade due to DTAs from equation (1) as:

$$\widehat{d^c_{ij,st}} = exp\left[-\frac{\widetilde{\alpha}_s}{\theta}\left(DTA_{ij,t} - DTA_{ij,1995}\right)\right],$$

[26]This approach is taken because some sectors in some economies are associated with both zero output and consumption in the WIOD due to differences in sector classifications across economies. Following Costinot and Rodríguez-Clare (2014), we thus aggregate to 31 sectors, all with non-zero outputs and consumption in all economies. This allows us to keep the data as disaggregated as possible. For further details, see pp. 14 of the Online Appendix of Costinot and Rodríguez-Clare (2014). See Appendix 2 for a list of economies and sectors and the aggregations included in our analysis.

[27]The aggregation scheme for economies is provided in Tables A5 and that for sectors and corresponding trade elasticities is provided in Table A6.

where $\widetilde{\alpha}_s$ is the point estimate of α in equation (1) for sector s (goods or services) and θ is the trade elasticity for each individual WIOD sector from Caliendo and Parro (2015), listed in Table A6. Then, the change in the bilateral trade costs from the contemporary estimates is given by:

$$\widehat{\phi}^c_{ij,st} = \widehat{d}^c_{ij,st} \frac{1+\tau_{ij,st}}{1+\tau_{ij,s1995}}, \tag{18}$$

where $\tau_{ij,st}$ is the tariff imposed by country i on sector s imports from country j.[28] Therefore, $\widehat{\phi}^c_{ij,st}$ measures overall changes in trade costs (including tariff and non-tariff barriers) between country i and country j in sector s from the year 1995 to year t.

Next, we consider the estimation result that incorporates the long-run effect of DTAs. From equation (2), changes in non-tariff barriers from period $t-1$ to t are given by:

$$\widehat{d}^l_{ij,st} = \exp\left[\sum_{a=1}^{3} -\frac{\widetilde{\alpha}_{a,s}}{\theta}\Delta DTA_{ij,t+a} - \frac{\widetilde{\alpha}_s}{\theta}\Delta DTA_{ij,t} + \sum_{m=1}^{3} -\frac{\widetilde{\alpha}_{m,s}}{\theta}\Delta DTA_{ij,t-m}\right],$$

while $\Delta DTA_{ij,t} = DTA_{ij,t} - DTA_{ij,t-1}$, and $\widetilde{\alpha}_{a,s}$, $\widetilde{\alpha}_s$, and $\widetilde{\alpha}_{m,s}$ are the point estimates of α_a, α and α_m for sector s (goods or services) in equation (2), respectively. Similarly, to capture the long-run effect of tariffs, we consider

$$\widehat{\Upsilon}_{ij,st} = \exp\left[\sum_{a=1}^{3} -\frac{\widetilde{\gamma}_{a,s}}{\theta} ln\frac{1+\tau_{ij,t+a}}{1+\tau_{ij,t-1+a}} - \sum_{m=1}^{3} \frac{\widetilde{\gamma}_{m,s}}{\theta} ln(\frac{1+\tau_{ij,t-m}}{\tau_{ij,t-1-m}})\right],$$

where $\widetilde{\gamma}_{a,s}$ and $\widetilde{\gamma}_{m,s}$ are point estimates of γ_a and γ_m for sector s (goods or services) in equation (2), respectively. We have excluded the contemporary effect of tariffs, which has already been captured in the model by equation (13). Overall, changes in trade costs from period $t-1$ to t which incorporate long-run effects are given by

$$\widehat{\phi}^l_{ij,st} = \widehat{d}^l_{ij,st}\widehat{\Upsilon}_{ij,st}\frac{1+\tau_{ij,st}}{1+\tau_{ij,st-1}}. \tag{19}$$

The accumulated changes in trade costs from year 1995 to year T is $\prod_{t=1996}^{T} \widehat{\phi}^l_{ij,st}$.

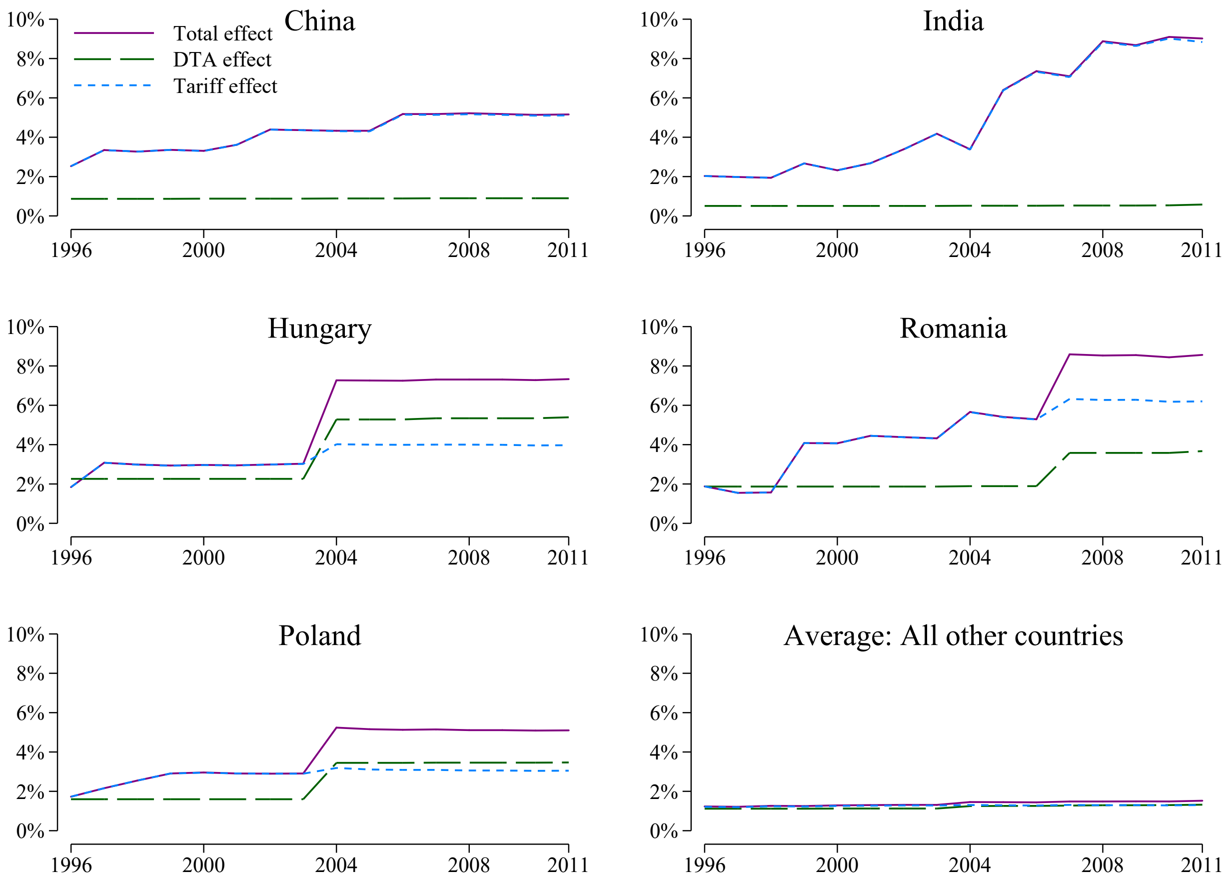
We feed the estimated trade cost shocks into the model together with data from the year 1995 to estimate changes in real consumption. Figure 3 plots the estimated changes in real consumption for each year when feeding trade cost shocks from contemporaneous estimates, which are further decomposed into DTA and tariff effects.[29] A few points are noteworthy in terms of overall welfare gains. First, Eastern European economies, including Romania, Hungary, and Poland, all of which

[28] For services sectors, there is no second term which captures changes in tariffs.

[29] The results from simulations that feed trade cost shocks estimated from the long-run specification are similar. Note that a general feature of this type of exercise is that the sum of the decomposition effects is typically larger than the total effect. This is explained by the fact that the baseline model accounts for a high-dimensional shock representing changes in both tariffs and DTAs. During the model simulation, these two components interact with one another, generating general equilibrium effects running in potentially different directions. When included in isolation, this potential interaction is not present. For other studies for which decomposition effects exhibit this feature, see Dhingra et al. (2017) and Tombe and Zhu (2019).

joined the EU during its 2004 enlargement, experienced high overall welfare gains. These gains were predominantly driven by tariff reductions prior to EU accession. After 2004, there is a notable rise in their welfare gains stemming from DTAs. Second, countries that cut their tariffs significantly, including China and India, stand out as well. For example, India's real consumption rose by almost 10% in 2011 compared to 1995 as a result of trade liberalization during this period. Unlike most of the Eastern European economies, China and India's welfare gains were driven predominantly by tariff reductions. All other economies in our sample experienced relatively small welfare gains over the period.[30]

Figure 3: Evolution of overall welfare gains from trade liberalization, 1996-2011



Notes: This figure shows the estimated change in real consumption for each economy and each year by feeding the observed changes in trade costs from the contemporaneous estimates using equation (1) as compared to year 1995 into the quantitative model.

Next, we use equation (17) to compute the consumption equivalent of welfare gains from trade liberalization from 1995-2011, assuming that $\beta = 0.96$ and that no further trade liberalization occurred after 2011. Following Costinot and Rodríguez-Clare (2014), we ensure consistency with the theoretical

[30] Appendix 2 presents all economies used in the quantitative analysis. Individual results for all economies not named in Figure 3 are averaged for readability and are available upon request.

model by performing simulations after having removed trade imbalances from the data. Note that this correction is made alongside an assumption of zero status quo tariffs (i.e., in 1995). In terms of the DTA variable, we assume that the "rest of the world" belongs to an agreement equal to the average depth with all other economies in our sample. Table 4 presents results: columns 1-5 present the results from feeding the trade cost shocks estimated from the contemporaneous specification shown in Table 2, and columns 6-7 present results from the long-run specification shown in Table 3.[31] In line with the picture painted by Figure 3, we find that China, India, and the Eastern European bloc benefited the most, enjoying a welfare gain ranging from roughly 4% to 7% in column 1. Other regions experienced modest welfare gains. Feeding the estimated trade costs from the long-run specification raises the average welfare gain from 2.05% to 2.34%, as demonstrated in column 6. This increase is mostly driven by the deepening integration of European countries. For other economies, the simulated welfare effects are quite close using the contemporaneous and long-run estimated trade costs shocks.[32] Given that our model is static, it might be more suited to capture changes over the long run. In column 7, we therefore accumulate the annual changes in trade costs from 1995-2011 and feed these cumulated changes to the model and compute the equivalent variation, assuming real consumptions grew linearly over time. The numbers are smaller than column 6 but the patterns are quite similar.

To understand the source of the welfare gain, Columns 2-5 conduct two additional exercises. First, in columns 2 and 3, we isolate the effects of DTA provisions from tariff shocks, and present the share attributable to each (i.e. columns 2 and 3 sum to 100%). Overall, we observe that gains from both types of trade liberalization are comparable. China and India are the main exceptions, as their gains from tariff liberalization are much bigger than those from deep clauses in trade agreements. This is not surprising: as we can see from Figure 2, these two economies undertook the largest import tariff cuts in our sample. Moreover, our results support the findings of Goldberg et al. (2010) and Yu (2015), who also show that reductions in China's and India's import tariffs contributed to aggregate gains.

Subsequently, columns 4 and 5 decompose total welfare gains into gains from goods versus services sectors, respectively (where now columns 4 and 5 sum to 100%). This exercise reveals that, in most cases, welfare gains from goods liberalization outweigh those from services liberalization. This is particularly evident for Eastern European economies (Hungary, Poland, and Romania) and emerging economies such as China and India and others like Mexico and Indonesia. On the other hand, the gains from goods versus services sectors are comparable for industrialized economies such as the US and early EU members.[33]

These results track well with intuition: industrialized economies exhibited low tariffs during the full sample period, and thus their gains from reductions in barriers to trade in goods are likely to be linked mostly to liberalization of non-tariff barriers to trade. On the other hand, developing

[31] For ease of computation, we even out the anticipation and maturation effect during their corresponding periods.

[32] As demonstrated in the Appendix Table A4, the effect of tariffs on trade is mostly contemporary while DTAs show significant long-run effects. Therefore, for countries like China and India, which did not sign significant DTAs during the sample period, there would be little extra gains incorporating the long-run estimates.

[33] For ease of discussion, columns 2-3 and 4-5 break down DTA and tariff results, and goods and services results, as shares.

Table 4: Welfare Effect of Trade Liberalization: 1995-2011

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Contemporaneous effect					Long-run responses	
	Baseline	DTA & tariff split		Goods & services split		DTAs & tariffs	
	DTAs & tariffs	DTA share	Tariff share	Goods share	Services share	Annual shock	Cumulated shock
AUS	1.97%	45.08%	54.92%	59.06%	40.94%	2.12%	1.80%
AUT	0.98%	53.44%	46.56%	56.59%	43.41%	1.17%	1.03%
BEL	1.41%	55.13%	44.87%	54.17%	45.83%	1.65%	1.43%
BRA	0.47%	51.02%	48.98%	50.51%	49.49%	0.48%	0.39%
CAN	1.54%	42.78%	57.22%	57.71%	42.29%	1.56%	1.24%
CHN	4.46%	16.21%	83.79%	84.10%	15.90%	4.49%	3.90%
DEU	1.08%	53.74%	46.26%	53.31%	46.69%	1.21%	1.01%
DNK	1.35%	50.82%	49.18%	56.42%	43.58%	1.51%	1.30%
ESP	0.72%	55.49%	44.51%	52.31%	47.69%	0.82%	0.68%
FIN	1.10%	51.91%	48.09%	56.04%	43.96%	1.27%	1.08%
FRA	0.81%	52.80%	47.20%	53.62%	46.38%	0.90%	0.74%
GBR	1.24%	52.00%	48.00%	53.47%	46.53%	1.36%	1.12%
GRC	0.65%	48.46%	51.54%	62.37%	37.63%	0.74%	0.65%
HUN	5.82%	55.20%	44.80%	70.13%	29.87%	8.33%	8.19%
IDN	2.09%	43.61%	56.39%	65.68%	34.32%	2.38%	2.25%
IND	6.61%	7.51%	92.49%	93.01%	6.99%	6.67%	6.82%
IRL	1.86%	52.18%	47.82%	52.34%	47.66%	2.01%	1.65%
ITA	0.96%	54.96%	45.04%	51.37%	48.63%	1.07%	0.87%
JPN	0.85%	51.17%	48.83%	49.57%	50.43%	0.86%	0.64%
KOR	2.29%	44.37%	55.63%	58.32%	41.68%	2.34%	1.84%
MEX	1.09%	38.33%	61.67%	66.56%	33.44%	1.19%	1.11%
NLD	1.67%	54.69%	45.31%	51.81%	48.19%	1.87%	1.56%
POL	4.23%	50.13%	49.87%	71.54%	28.46%	5.77%	5.46%
PRT	0.70%	60.63%	39.37%	50.50%	49.50%	0.84%	0.72%
ROU	6.53%	36.22%	63.78%	77.31%	22.69%	8.07%	8.27%
RUS	2.40%	49.79%	50.21%	51.67%	48.33%	2.47%	2.06%
SWE	1.06%	51.79%	48.21%	54.53%	45.47%	1.18%	0.99%
TUR	1.51%	56.68%	43.32%	59.06%	40.94%	1.48%	1.17%
TWN	3.03%	46.25%	53.75%	54.29%	45.71%	3.06%	2.51%
USA	0.84%	51.57%	48.43%	49.20%	50.80%	0.86%	0.67%
RoW	2.38%	38.97%	61.03%	73.35%	26.65%	2.73%	2.56%
average	2.05%	44.04%	55.96%	64.24%	35.76%	2.34%	2.12%

Notes: This table presents the welfare effect of trade liberalization during 1995-2011 in terms of equivalent variation for each economy. Columns 1-5 present results from simulations which feed the estimated changes in trade costs from the contemporaneous effect specification (equation 1) to the model. Columns 6 and 7 present results from simulations which feed the estimated trade costs that include the dynamic effects other than contemporary effects (equation 2). Column 1 simulates the overall welfare effects of DTA and tariff shocks. Columns 2 and 3 feed the DTA and tariff shocks in isolation, respectively, and present results in terms of shares. Similarly, columns 4 and 5 decompose the effects into gains from trade liberalization in goods versus services sectors, respectively. Column 6 feeds the estimated annual changes in trade costs due to contemporary, anticipation, and phase-in effects of trade agreements to the model. Column 7 accumulates the annual changes in trade costs from 1995-2011 and feed these cumulated changes to the model and compute the equivalent variation, assuming real consumptions grew linearly over time. In all columns, we assume the discount factor $\beta = 0.96$. The last row of the table computes the simple average of welfare gains across economies.

and emerging market economies drastically cut their tariffs during the sample period and undertook deeper liberalizations, and thus their gains from trade in goods are likely to capture both effects. Moreover, welfare gains from services sectors are non-trivial, which speaks to the importance of deep commitments in services trade. It is also noteworthy that welfare gains from column 5 tend to be smaller than those in column 2. This is rationalized by the fact that results in column 2 account for DTA effects for all sectors over time, whereas those in column 5 isolate DTA effects for services sectors only.

In Appendix Table A7, we conduct decompositions of welfare for simulations examining trade cost shocks incorporating long-run effects. For the decomposition between DTAs and tariffs, incorporating long-run effects raises the relative importance of DTAs, especially for the Eastern European countries. This is because the effect of tariffs on trade is predominantly contemporary while DTAs show significant long-run effects (see Appendix Table A4). Similarly, we find the importance of trade liberalization in goods sectors increases slightly relative to services sectors.

Finally, we conduct a battery of robustness checks on welfare gains in Table 5. Columns 2 and 3 present the results of two robustness exercises. First, in column 2 we re-estimate our baseline specification from column 1, but instead of assuming zero status quo tariffs when removing trade imbalances in the year 1995, we now impose actual applied tariff rates in this year. The resulting welfare gains remain very close to those in the baseline. In column 3, we use a discount factor $\beta = 0.99$, which raises welfare gains slightly. In columns 4-6, instead of using the estimated trade elasticities for goods sectors from Caliendo and Parro (2015), we use the estimated elasticities by Freeman et al. (2021) which exploit structural gravity equations to back out the elasticity for both goods and services sectors in a theory-consistent manner. Column 4 re-estimates the welfare gains feeding the estimated trade shocks from the contemporaneous specification, and columns 5 and 6 the long-run specification. Although the average welfare gains are smaller than the baseline, the main patterns are similar.

Table 5: Robustness Checks on the Welfare Effect of Trade Liberalization

	(1)	(2)	(3)	(4)	(5)	(6)
	Elasticties: Caliendo and Parro (2015)			Elasticties: Freeman et al. (2021)		
	Baseline contemporaneous	Actual '95 tariffs	Discount $\beta = 0.99$	Baseline contemporaneous	Annual shock	Cumulated shock
AUS	1.97%	1.96%	2.11%	1.82%	1.89%	1.57%
AUT	0.98%	0.96%	1.07%	0.89%	1.00%	0.85%
BEL	1.41%	1.35%	1.53%	1.21%	1.32%	1.09%
BRA	0.47%	0.49%	0.49%	0.45%	0.46%	0.37%
CAN	1.54%	1.54%	1.61%	1.45%	1.47%	1.16%
CHN	4.46%	4.80%	4.97%	3.35%	3.38%	2.91%
DEU	1.08%	1.03%	1.14%	1.02%	1.09%	0.88%
DNK	1.35%	1.34%	1.47%	1.30%	1.38%	1.16%
ESP	0.72%	0.70%	0.76%	0.70%	0.74%	0.60%
FIN	1.10%	1.08%	1.17%	0.89%	0.96%	0.79%
FRA	0.81%	0.79%	0.86%	0.75%	0.79%	0.64%
GBR	1.24%	1.20%	1.30%	1.17%	1.23%	0.99%
GRC	0.65%	0.66%	0.71%	0.50%	0.54%	0.45%
HUN	5.82%	5.90%	6.91%	4.33%	5.67%	5.45%
IDN	2.09%	2.16%	2.40%	1.75%	1.86%	1.64%
IND	6.61%	6.82%	8.33%	2.04%	2.08%	2.03%
IRL	1.86%	1.83%	1.95%	1.80%	1.91%	1.57%
ITA	0.96%	0.93%	1.00%	0.88%	0.93%	0.75%
JPN	0.85%	0.80%	0.84%	0.79%	0.81%	0.63%
KOR	2.29%	2.34%	2.36%	1.80%	1.84%	1.45%
MEX	1.09%	1.14%	1.28%	0.87%	0.92%	0.82%
NLD	1.67%	1.59%	1.76%	1.58%	1.69%	1.39%
POL	4.23%	4.23%	4.86%	2.72%	3.59%	3.40%
PRT	0.70%	0.68%	0.74%	0.65%	0.70%	0.56%
ROU	6.53%	6.64%	7.98%	3.86%	4.78%	4.80%
RUS	2.40%	2.30%	2.58%	2.51%	2.55%	2.11%
SWE	1.06%	1.03%	1.13%	0.96%	1.03%	0.85%
TUR	1.51%	1.52%	1.55%	1.08%	1.07%	0.82%
TWN	3.03%	3.14%	3.23%	2.85%	2.89%	2.35%
USA	0.84%	0.80%	0.86%	0.83%	0.85%	0.66%
RoW	2.38%	2.56%	2.75%	1.55%	1.68%	1.53%
average	2.05%	2.07%	2.31%	1.56%	1.71%	1.49%

Notes: Columns 1-3 simulate the model using trade elasticities from Caliendo and Parro (2015). Columns 4-6 simulate the model using trade elasticities from Freeman et al. (2021). Column 1 is the same as column 1 of Table 4. Column 2 uses data which removes trade imbalances using the model assuming the underlying status-quo tariffs are actual tariffs in year 1995. Column 3 uses a discount factor $\beta = 0.99$. Column 4 simulates the same scenario as column 1 of Table 4 but uses trade elasticities from Freeman et al. (2021). Columns 5 and 6 follow the same specifications as columns 6 and 7 from Table 4, respectively, but use trade elasticities from Freeman et al. (2021).

5.2 Brexit and post-Brexit trade deals

The United Kingdom's decision to withdraw from the EU is an unprecedented instance of trade de-integration: it is the first time in modern history that an economy has sought to leave a deeply integrated trading bloc. As such, Brexit represents a potentially significant re-shaping of the UK's future trading relationships with both the EU itself and the rest of the world. In addition, leaving the EU affords the UK the opportunity to independently negotiate trade agreements with non-EU countries, which it was unable to do while within the EU. Although it remains unclear which countries these might be, the US and the UK's Commonwealth trading partners are frequently cited as potential candidates. The depth of any possible new trade agreements with non-EU countries remains uncertain.

The importance of this policy question and the uncertainty surrounding any outcome has sparked several investigations into the potential consequences of Brexit, including Dhingra et al. (2017), Born et al. (2019), Steinberg (2019), and Mayer et al. (2019), among others. In this subsection, we pick up on this debate, and focus on the welfare effect of Brexit and post-Brexit trade agreements. Importantly, our analysis differs from those mentioned above in two main ways. First, instead of proxying any new deal with a binary trade agreement variable, we use information from our reduced-form estimates in equation (1), which account for the depth of agreements based on non-tariff provisions. Second, we incorporate the actual information about potential tariff shocks based on pre-existing bilateral tariff rates between trade partners.

Overall, we consider four potential Brexit outcomes, summarized in Table 6.[34] While the UK's future tariffs with the EU have been specified in the new EU-UK Trade and Cooperation Agreement (TCA), its implications for non-tariff barriers, particularly in the services sectors, are not fully specified. We therefore consider different degrees of depth in the UK's trading relationship within and outside the EU.

Table 6: Brexit scenarios

Scenario	(a) UK: Soft Brexit with the EU	(b) UK: Hard Brexit with the EU
1	*NAFTA-depth deal with EU*	*No deal with the EU; MFN rules*
2	*Scenario (1a) plus NAFTA-depth trade deal with the United States*	—
3	*Scenario (2a) plus NAFTA-depth trade deal with Canada and Australia*	—

Notes: This table describes the four different Brexit scenarios considered in our counterfactual exercises. In all scenarios, we assume that current FTAs with non-EU members remain in place.

The first three scenarios relate to a "Soft Brexit" case, in which the UK and EU are assumed to negotiate a trade deal of equivalent depth and tariff rates as the North American Free Trade Agreement (NAFTA). NAFTA is a relatively deep agreement, encompassing 0% preferential tariff rates on nearly all goods and a range of non-tariff provisions. The main difference between this Soft Brexit outcome and the UK's EU membership is thus a shift in non-tariff barriers.[35] For example, according to the DTA database, the EU agreement contains provisions on areas like competition policy, anti-corruption, and visa and asylum, while NAFTA does not. The remaining two Soft Brexit scenarios layer additional

[34] In all scenarios, we assume that the UK rolls over its pre-existing trade deals with non-EU members. These are less important here, as most agreements are relatively shallow in nature.

[35] There are some differences in tariff rates on individual products, but the main differences come in terms of non-tariff barriers to trade.

NAFTA-depth agreements (including NAFTA tariff rates) on top of the assumed UK-EU relationship. First, we allow for such an agreement between the UK and US, the UK's next largest trading partner. Second, we consider additional agreements between the UK and its largest Commonwealth trading partners, Canada and Australia.

The final scenario relates to a benchmark "Hard Brexit", whereby the UK trades on MFN terms with the entire EU bloc: bilateral tariffs revert to MFN rates, and trade agreement depth drops to zero. This is a useful benchmark with which to compare our estimates because previous work has typically reported a Hard Brexit scenario, as the chance of a no deal remained on the table until the UK actually left the EU in 2021. In all cases, we choose the final year of our data as the base year of Brexit and feed the data from this year into the model alongside the shocks from the four different Brexit scenarios.

Table 7 presents the welfare effects in terms of changes in real consumption from different Brexit and post-Brexit trade deals.[36] Columns 1-3 present results relating to the various Soft Brexit outcomes, and column 4 presents results relating to the Hard Brexit outcomes. Columns 5-8 re-examine the scenarios in columns 1-4 respectively by feeding the implied trade costs from estimation results from long-run specifications. We discuss these outcomes in turn.

UK: Soft Brexit with the EU. Column 1 of Table 7 presents results from a basic Soft Brexit scenario, whereby we assume that the UK reaches a NAFTA-depth agreement with the EU and implements NAFTA tariff rates. In this case, we infer the associated change in DTA provisions using the estimated $\widehat{\alpha}_s$ point estimate from equation (1) and the difference between the depth of NAFTA and the EU.[37] Under this scenario, we find that UK welfare would drop by 1.02%. Ireland experiences the next biggest welfare reduction, 0.59%. Other EU members are also left worse off, but the hit to their welfare is about one order of magnitude smaller. Economies outside the EU gain slightly from Brexit due to trade diversion effects. Column 2 presents results when layering a NAFTA-depth UK-US trade deal and NAFTA-level UK-US tariff rates on top of Soft Brexit with the EU. This reduces the UK's welfare loss by about a third. The US' welfare is only slightly raised, and the welfare of most of the other regions remains almost unchanged. Finally, column 3 allows for NAFTA-like DTAs between the UK and the US, Canada, and Australia. Columns 5-7 use the long-run estimate. We find that the magnitude of welfare changes almost doubles.

The main takeaways from the Soft Brexit counterfactuals are twofold. Even with this relatively deep post-Brexit trade agreement with the EU, UK welfare declines as a result of leaving the EU. Furthermore, additional DTAs with non-EU members do little to mitigate this loss. In the best-case scenario (column 3), the UK still experiences a welfare loss of 0.67% (over two-thirds of the loss without the extra deals).

UK: Hard Brexit with the EU. Column 4 of Table 7 presents results from our baseline Hard Brexit scenario, whereby we assume that no trade deal is reached between the UK and the EU. In such

[36]We assume that the Brexit shock is permanent. Therefore, computing the consumption equivalent would deliver the same result.

[37]In the year 2011, the EU's depth index is 1, while that of NAFTA is 0.5.

Table 7: Welfare effects of Brexit

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Contemporaneous effect				Long-run responses			
	UK: Soft Brexit with the EU			Hard Brexit	UK: Soft Brexit with the EU			Hard Brexit
		+ NAFTA-depth DTA with:				*+ NAFTA-depth DTA with:*		
		US	US, CAN, AUS			US	US, CAN, AUS	
AUS	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%
AUT	-0.07%	-0.07%	-0.07%	-0.13%	-0.12%	-0.12%	-0.12%	-0.22%
BEL	-0.21%	-0.22%	-0.22%	-0.40%	-0.37%	-0.38%	-0.38%	-0.67%
BRA	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CAN	0.03%	0.03%	0.11%	0.03%	0.03%	0.03%	0.18%	0.03%
CHN	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.01%
DEU	-0.15%	-0.16%	-0.16%	-0.30%	-0.28%	-0.28%	-0.28%	-0.51%
DNK	-0.11%	-0.11%	-0.11%	-0.23%	-0.19%	-0.19%	-0.19%	-0.37%
ESP	-0.08%	-0.08%	-0.08%	-0.14%	-0.14%	-0.14%	-0.14%	-0.25%
FIN	-0.09%	-0.09%	-0.09%	-0.15%	-0.15%	-0.16%	-0.16%	-0.27%
FRA	-0.09%	-0.09%	-0.09%	-0.17%	-0.16%	-0.17%	-0.17%	-0.30%
GBR	**-1.02%**	**-0.70%**	**-0.67%**	**-2.24%**	**-1.98%**	**-1.34%**	**-1.28%**	**-3.90%**
GRC	-0.04%	-0.04%	-0.04%	-0.08%	-0.07%	-0.07%	-0.07%	-0.13%
HUN	-0.12%	-0.13%	-0.13%	-0.25%	-0.22%	-0.22%	-0.22%	-0.41%
IDN	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
IND	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
IRL	-0.59%	-0.60%	-0.61%	-1.21%	-1.05%	-1.07%	-1.07%	-1.99%
ITA	-0.06%	-0.06%	-0.06%	-0.11%	-0.10%	-0.10%	-0.10%	-0.18%
JPN	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
KOR	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.01%
MEX	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
NLD	-0.17%	-0.18%	-0.18%	-0.35%	-0.30%	-0.31%	-0.31%	-0.57%
POL	-0.09%	-0.09%	-0.09%	-0.18%	-0.16%	-0.16%	-0.16%	-0.30%
PRT	-0.07%	-0.07%	-0.07%	-0.14%	-0.13%	-0.13%	-0.13%	-0.23%
ROU	-0.08%	-0.08%	-0.08%	-0.14%	-0.14%	-0.14%	-0.14%	-0.25%
RUS	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SWE	-0.13%	-0.13%	-0.13%	-0.23%	-0.22%	-0.22%	-0.23%	-0.40%
TUR	0.00%	0.00%	0.00%	0.02%	0.01%	0.01%	0.01%	0.02%
TWN	0.00%	0.00%	0.00%	0.01%	0.01%	0.00%	0.00%	0.02%
USA	0.01%	0.04%	0.04%	0.02%	0.01%	0.07%	0.07%	0.02%
RoW	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.01%

Notes: This table shows the impact of the following scenarios on the welfare (in terms of real consumption) of each economy: (1) Soft Brexit. The UK and the EU reach a NAFTA-depth trade deal (including NAFTA tariff rates). (2) In addition, a NAFTA-depth and NAFTA-tariff rate deal is reached with the United States. (3) In addition, a NAFTA-depth and NAFTA-tariff rate deal is reached with Canada and Australia. (4) Hard Brexit. There is no deal between the UK and the EU: depth is zero, and each apply MFN tariffs. Columns 1-4 infer the associated changes in trade costs using our contemporaneous effect specification (equation 1). Columns 5-8 infer the associated changes in trade costs using our specification considering anticipation and phase-in effects of trade agreements (equation 2).

a world, the depth between the UK and all EU trade partners would drop to zero, and MFN tariffs would be implemented. Compared to our baseline Soft Brexit scenario (column 1), the hit to welfare more than doubles reaching a total loss of 2.24%. Taking into account the long-run effect, welfare loss can be even bigger, rising to 3.90% in column 8. This shows that a deeper agreement like the TCA can potentially avoid the losses from a Hard Btrexit scenario but its potential to do so is smaller than a Soft Brexit scenario. A substantively Soft Brexit nonetheless entails losses in economic welfare that are an order of magnitude higher than those estimated for the US economy from the Trump tariff war (0.04% of GDP, Fajgelbaum et al. 2020).

Clearly, the main takeaway from these exercises is that signing deep trade deals with non-EU members will not make up for the overall loss from leaving the EU. Admittedly, a welfare loss of around 1% (Soft Brexit) to 2% (Hard Brexit) might seem modest, but they are incurred annually over the period during which the UK remains under the TCA.[38] To put these numbers in perspective, we can compare with column 1 of Table 4, which shows that total UK welfare gains from trade liberalization over the 1995-2011 period were just over 1.2%. Therefore, we conclude that Brexit losses are of a similar magnitude as the gains from trade liberalization accumulated over nearly two decades.

6 Conclusion

This paper has examined the impact of deep trade agreements (DTAs) on trade and welfare. The reduced-form estimates show that deep trade policy commitments have given an extra boost to trade in goods. A less well-known finding is that deep trade policy commitments increase trade in services. These reduced-form estimates provide direct evidence for the role of DTAs in fostering international economic integration. To examine the welfare effect of DTAs, the paper develops a structural model that builds on the reduced-form estimates to determine the aggregate welfare impacts of deep trade policy commitments.

The structural model enables an understanding of the aggregate contribution of DTAs to the welfare gains from trade in the last couple of decades. We find that the tariff reductions and deepening of trade policy commitments since the Uruguay Round increased welfare by over 2% on average. DTAs contributed over 40% to the gains from trade, and even more so in advanced economies and 2004 EU-accession members.

A key advantage of structural modeling is the ability to conduct counterfactual scenario analysis. Applying the reduced-form estimates and the structural model to Brexit, we find that the UK economy experiences a welfare loss ranging from roughly -2% to -4% in the long run under the Hard Brexit scenario. While signing deep agreements with the EU and key trading partners like the United States, Canada, and Australia reduces the magnitude of the welfare losses, it is not enough to overcome the loss of deep trade policy commitments that EU membership provides. Welfare losses in this soft Brexit scenario continue to be negative. The annual welfare losses under our baseline Soft Brexit scenario

[38]Our Hard Brexit numbers are similar to those from Dhingra et al. (2017) and a wide range of other studies. See Sampson (2017) for a survey.

amount to over 80% of the UK's annual gains from trade liberalization accumulated in the 16 years following the conclusion of the Uruguay Round.

This paper quantifies the trade and welfare gains from deep trade policy commitments. DTAs have contributed substantially to the overall gains from trade and continue to be important for many economies, particularly as tariffs have reached low levels. As trends towards deglobalization continue, precise quantification of the potential aggregate gains from deep trade agreements—as provided by this paper—is essential to enable a thorough assessment of alternative trade policies and their concomitant trade-offs.

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Appendix 1 Additional results

This appendix presents additional results as referred to in the main text. Tables A1 and A2 estimate equations (1) and (2), respectively, whereby we new include provisions which are weakly legally enforceable, i.e. do not include dispute settlement. In Table A1 we present results using annual, two-year, and four-year interval data. In Table A2 we use annual data and show the anticipation, maturation, and total DTA and tariff effects. Table A3 estimates equation (1), however, instead of using annual data we rely upon two-year and four-year interval data to capture the adjustment of trade flows to trade agreements. Finally, Table A4 presents full results corresponding to equation (2).

Table A1: Additional provision category - Contemporaneous agreement effects

	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
	Aggregate Exports		Goods Exports		Services Exports	
	$Core_{ij,t}$	$Depth_{ij,t}$	$Core_{ij,t}$	$Depth_{ij,t}$	$Core_{ij,t}$	$Depth_{ij,t}$
Panel A: Annual data						
$DTA_{ij,t}$	0.103**	0.126***	0.164***	0.202***	0.220***	0.232***
	(0.043)	(0.043)	(0.055)	(0.055)	(0.035)	(0.038)
$ln(1+\tau_{ij,t})$	-0.230***	-0.227***	-0.266***	-0.261***		
	(0.038)	(0.037)	(0.038)	(0.038)		
FEs (it, jt, ij)	Yes	Yes	Yes	Yes	Yes	Yes
Observations	27,191	27,191	26,434	26,434	27,200	27,200
Panel B: Two-year interval data						
$DTA_{ij,t}$	0.109***	0.128***	0.146***	0.180***	0.261***	0.268***
	(0.041)	(0.042)	(0.052)	(0.054)	(0.039)	(0.041)
$ln(1+\tau_{ij,t})$	-0.236***	-0.234***	-0.285***	-0.281***		
	(0.036)	(0.036)	(0.037)	(0.037)		
FEs (it, jt, ij)	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,395	14,395	13,917	13,917	14,400	14,400
Panel C: Four-year interval data						
$DTA_{ij,t}$	0.114***	0.130***	0.131***	0.158***	0.254***	0.251***
	(0.039)	(0.041)	(0.051)	(0.053)	(0.047)	(0.050)
$ln(1+\tau_{ij,t})$	-0.298***	-0.298***	-0.341***	-0.339***		
	(0.032)	(0.032)	(0.034)	(0.033)		
FEs (it, jt, ij)	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,995	7,995	7,677	7,677	8,000	8,000

Notes: This table shows full estimation results for equation (1) for aggregate gross exports, goods exports, and services exports. Data is for years 1995-2011 in annual intervals (Panel A), two-year intervals (Panel B), and four-year intervals (Panel C). We now include provisions which are weakly legally enforceable, i.e., do not include dispute settlement. RoW aggregate excluded. SEs clustered by ij-pair are in parentheses. *, **, and *** denote statistical significance at the 10, 5, and 1% levels, respectively.

Table A2: Additional provision category - Anticipation, maturation, and total effects

	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
	Aggregate Exports		Goods Exports		Services Exports	
	$Core_{ij,t}$	$Depth_{ij,t}$	$Core_{ij,t}$	$Depth_{ij,t}$	$Core_{ij,t}$	$Depth_{ij,t}$
(1): $\sum_{a=1}^{3} \alpha_a DTA_{ij,t+a}$	0.146***	0.172***	0.173***	0.207***	0.190***	0.219***
	(0.042)	(0.041)	(0.057)	(0.055)	(0.041)	(0.040)
(2): $\alpha + \sum_{m=1}^{3} \alpha_m DTA_{ij,t-m}$	0.141***	0.139***	0.192***	0.196***	0.228***	0.219***
	(0.046)	(0.046)	(0.052)	(0.052)	(0.053)	(0.053)
Total DTA effect = (1) + (2)	0.288***	0.312***	0.364***	0.403***	0.418***	0.438***
	(0.066)	(0.065)	(0.088)	(0.086)	(0.049)	(0.051)
(3): $\sum_{a=1}^{3} \gamma_a ln(1+\tau_{ij,t+a})$ ln(1+t_ijt)	0.026	0.028	-0.026	-0.025		
	(0.042)	(0.042)	(0.048)	(0.048)		
(4): $\gamma + \sum_{m=1}^{3} \gamma_m ln(1+\tau_{ij,t-m})$	-0.160***	-0.160***	-0.126***	-0.123***		
	(0.050)	(0.050)	(0.043)	(0.043)		
Total tariff effect = (3) + (4)	-0.134**	-0.132**	-0.151***	-0.148***		
	(0.053)	(0.052)	(0.057)	(0.057)		
FEs (it, jt, ij)	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17,588	17,588	16,831	16,831	17,600	17,600

Notes: This table shows full estimation results for equation (2) for aggregate gross exports, goods exports, and services exports. Data is for years 1995-2011 (annual). We now include provisions which are weakly legally enforceable, i.e., do not include dispute settlement. RoW aggregate excluded. SEs clustered by ij-pair are in parentheses. *, **, and *** denote statistical significance at the 10, 5, and 1% levels, respectively.

Table A3: Contemporaneous agreement effects with interval data

	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)	(3a)	(3b)	(3c)
	Aggregate Exports			Goods Exports			Services Exports		
	$EIA_{ij,t}$	$Core_{ij,t}$	$Depth_{ij,t}$	$EIA_{ij,t}$	$Core_{ij,t}$	$Depth_{ij,t}$	$EIA_{ij,t}$	$Core_{ij,t}$	$Depth_{ij,t}$
Panel A: 2-year interval data									
$DTA_{ij,t}$	0.101***	0.118***	0.140***	0.108**	0.162***	0.199***	0.223***	0.280***	0.295***
	(0.039)	(0.043)	(0.043)	(0.048)	(0.055)	(0.056)	(0.038)	(0.041)	(0.042)
$ln(1+\tau_{ij,t})$	-0.236***	-0.235***	-0.234***	-0.290***	-0.283***	-0.280***			
	(0.036)	(0.036)	(0.035)	(0.037)	(0.037)	(0.036)			
FEs (it, jt, ij)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,395	14,395	14,395	13,917	13,917	13,917	14,400	14,400	14,400
Panel B: 4-year interval data									
$DTA_{ij,t}$	0.096***	0.126***	0.145***	0.087*	0.148***	0.176***	0.223***	0.274***	0.279***
	(0.036)	(0.041)	(0.042)	(0.046)	(0.054)	(0.056)	(0.046)	(0.050)	(0.051)
$ln(1+\tau_{ij,t})$	-0.301***	-0.297***	-0.297***	-0.348***	-0.340***	-0.339***			
	(0.032)	(0.032)	(0.031)	(0.034)	(0.034)	(0.033)			
FEs (it, jt, ij)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,995	7,995	7,995	7,677	7,677	7,677	8,000	8,000	8,000

Notes: This table shows full estimation results for equation (1) for aggregate gross exports, goods exports, and services exports. Data is for years 1995-2011 in two-year intervals (Panel A) and four-year intervals (Panel B). RoW aggregate excluded. SEs clustered by ij-pair are in parentheses. *, **, and *** denote statistical significance at the 10, 5, and 1% levels, respectively.

Table A4: Full results - Anticipation, maturation, and total effects

	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)	(3a)	(3b)	(3c)
	Aggregate Exports			Goods Exports			Services Exports		
	$EIA_{ij,t}$	$Core_{ij,t}$	$Depth_{ij,t}$	$EIA_{ij,t}$	$Core_{ij,t}$	$Depth_{ij,t}$	$EIA_{ij,t}$	$Core_{ij,t}$	$Depth_{ij,t}$
$DTA_{ij,t+3}$	0.117***	0.138***	0.147***	0.079**	0.103**	0.120***	0.189***	0.224***	0.218***
	(0.034)	(0.036)	(0.035)	(0.037)	(0.041)	(0.040)	(0.055)	(0.058)	(0.048)
$DTA_{ij,t+2}$	-0.071***	-0.085***	-0.069***	-0.023	-0.021	-0.005	-0.187***	-0.193***	-0.153***
	(0.022)	(0.023)	(0.020)	(0.027)	(0.027)	(0.022)	(0.055)	(0.054)	(0.043)
$DTA_{ij,t+1}$	0.098***	0.097***	0.095***	0.088***	0.096***	0.098***	0.154***	0.165***	0.151***
	(0.022)	(0.022)	(0.021)	(0.023)	(0.024)	(0.023)	(0.040)	(0.039)	(0.033)
$DTA_{ij,t}$	-0.012	-0.020	-0.032	0.035	0.037	0.033	0.062**	0.067**	0.060**
	(0.027)	(0.029)	(0.029)	(0.023)	(0.026)	(0.027)	(0.029)	(0.031)	(0.030)
$DTA_{ij,t-1}$	0.021	0.026	0.030**	0.018	0.029	0.028*	0.027	0.032	0.034
	(0.016)	(0.016)	(0.015)	(0.018)	(0.018)	(0.016)	(0.024)	(0.024)	(0.024)
$DTA_{ij,t-2}$	0.082***	0.104***	0.108***	0.077***	0.102***	0.108***	0.052*	0.090***	0.093***
	(0.015)	(0.015)	(0.015)	(0.018)	(0.019)	(0.019)	(0.031)	(0.029)	(0.026)
$DTA_{ij,t-3}$	0.032	0.044**	0.054***	0.031	0.038	0.040	0.049	0.060	0.069**
	(0.023)	(0.022)	(0.021)	(0.027)	(0.026)	(0.025)	(0.038)	(0.038)	(0.031)
$ln(1+\tau_{ij,t+3})$	0.024	0.023	0.020	-0.015	-0.019	-0.023			
	(0.041)	(0.041)	(0.041)	(0.040)	(0.039)	(0.039)			
$ln(1+\tau_{ij,t+2})$	-0.035*	-0.037**	-0.035*	-0.040**	-0.040**	-0.038*			
	(0.018)	(0.018)	(0.018)	(0.020)	(0.020)	(0.020)			
$ln(1+\tau_{ij,t+1})$	0.041	0.037	0.035	0.031	0.027	0.025			
	(0.027)	(0.027)	(0.027)	(0.029)	(0.029)	(0.028)			
$ln(1+\tau_{ij,t})$	-0.219***	-0.221***	-0.225***	-0.122***	-0.123***	-0.125***			
	(0.037)	(0.038)	(0.038)	(0.028)	(0.028)	(0.028)			
$ln(1+\tau_{ij,t-1})$	0.026	0.027	0.027	0.004	0.006	0.005			
	(0.019)	(0.019)	(0.019)	(0.017)	(0.017)	(0.017)			
$ln(1+\tau_{ij,t-2})$	0.017	0.024	0.026	0.012	0.020	0.022			
	(0.017)	(0.017)	(0.017)	(0.015)	(0.015)	(0.015)			
$ln(1+\tau_{ij,t-3})$	0.011	0.014	0.018	-0.028	-0.023	-0.018			
	(0.024)	(0.024)	(0.024)	(0.028)	(0.027)	(0.027)			
(1): $\sum_{a=1}^{3} \alpha_a DTA_{ij,t+a}$	0.144***	0.150***	0.174***	0.145***	0.178***	0.212***	0.156***	0.196***	0.216***
	(0.042)	(0.043)	(0.040)	(0.055)	(0.057)	(0.053)	(0.041)	(0.041)	(0.039)
(2): $\alpha + \sum_{m=1}^{3} \alpha_m DTA_{ij,t-m}$	0.122***	0.154***	0.160***	0.160***	0.205***	0.209***	0.189***	0.249***	0.256***
	(0.045)	(0.047)	(0.047)	(0.050)	(0.053)	(0.053)	(0.051)	(0.055)	(0.056)
Total DTA effect = (1) + (2)	0.266***	0.304***	0.334***	0.305***	0.383***	0.422***	0.345***	0.445***	0.472***
	(0.065)	(0.066)	(0.063)	(0.083)	(0.088)	(0.084)	(0.045)	(0.051)	(0.054)
(3): $\sum_{a=1}^{3} \gamma_a ln(1+\tau_{ij,t+a})$	0.030	0.022	0.020	-0.024	-0.032	-0.036			
	(0.042)	(0.042)	(0.043)	(0.049)	(0.048)	(0.048)			
(4): $\gamma + \sum_{m=1}^{3} \gamma_m ln(1+\tau_{ij,t-m})$	-0.165***	-0.156***	-0.155***	-0.134***	-0.120***	-0.116***			
	(0.050)	(0.050)	(0.051)	(0.044)	(0.044)	(0.044)			
Total tariff effect = (3) + (4)	-0.135**	-0.134***	-0.134***	-0.158***	-0.153***	-0.153***			
	(0.053)	(0.052)	(0.051)	(0.058)	(0.057)	(0.056)			
FEs (it, jt, ij)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17,588	17,588	17,588	16,831	16,831	16,831	17,600	17,600	17,600

Notes: This table shows full estimation results for equation (2) for aggregate gross exports, goods exports, and services exports. Data is for years 1995-2011. RoW aggregate excluded. SEs clustered by ij-pair are in parentheses. *, **, and *** denote statistical significance at the 10, 5, and 1% levels, respectively.

Appendix 2 WIOD Regions and Sectors

Table A5: WIOD economies and aggregation

WIOD Region	WIOD Code	Quantitative model aggregation
Australia	AUS	AUS
Austria	AUT	AUT
Belgium	BEL	BEL
Brazil	BRA	BRA
Canada	CAN	CAN
China	CHN	CHN
Denmark	DNK	DNK
Finland	FIN	FIN
France	FRA	FRA
Germany	DEU	DEU
Greece	GRC	GRC
Hungary	HUN	HUN
India	IND	IDN
Indonesia	IDN	IND
Ireland	IRL	IRL
Italy	ITA	ITA
Japan	JPN	JPN
Korea	KOR	KOR
Mexico	MEX	MEX
Netherlands	NLD	NLD
Poland	POL	POL
Portugal	PRT	PRT
Romania	ROU	ROU
Russia	RUS	RUS
Spain	ESP	ESP
Sweeden	SWE	SWE
Taiwan	TWN	TWN
Turkey	TUR	TUR
United Kingdom	GBR	GBR
United States	USA	USA
Bulgaria	BGR	
Cyprus	CYP	
Czech Republic	CZE	
Estonia	EST	
Latvia	LVA	
Lithuania	LTU	RoW
Luxembourg	LUX	
Malta	MLT	
Slovak Republic	SVK	
Slovenia	SVN	
Rest of World	RoW	

Notes: We aggregate economies shown in columns 1 and 2 into those in column 3 for the estimation of the quantitative model.

Table A6: WIOD sectors, trade elasticities and sector aggregation used in analysis

WIOD Sector	WIOD Sector Description	Detailed Sector Aggregation	Trade Elasticity	Aggregate Sectors (Goods vs. Services)
1	Agriculture, Hunting, Forestry and Fishing	1	8.11	Goods
2	Mining and Quarrying	2	15.72	Goods
3	Food, Beverages and Tobacco	3	2.55	Goods
4	Textiles and Textile Products	4	5.56	Goods
5	Leather, Leather and Footwear			
6	Wood and Products of Wood and Cork	5	10.83	Goods
7	Pulp, Paper, Paper Printing and Publishing	6	9.07	Goods
8	Coke, Refined Petroleum and Nuclear Fuel	7	51.08	Goods
9	Chemicals and Chemical Products	8	4.75	Goods
10	Rubber and Plastics	9	1.66	Goods
11	Other Non-Metallic Mineral	10	2.76	Goods
12	Basic Metals and Fabricated Metal	11	7.99	Goods
13	Machinery, Nec	12	1.52	Goods
14	Electrical and Optical Equipment	13	10.6	Goods
15	Transport Equipment	14	0.37	Goods
16	Manufacturing, Nec; Recycling	15	5	Goods
17	Electricity, Gas and Water Supply	16	5	Services
18	Construction	17	5	Services
19	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	18	5	Services
20	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles			
21	Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	19	5	Services
22	Hotels and Restaurants	20	5	Services
23	Inland Transport	21	5	Services
24	Water Transport	22	5	Services
25	Air Transport	23	5	Services
26	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	24	5	Services
27	Post and Telecommunications	25	5	Services
28	Financial Intermediation	26	5	Services
29	Real Estate Activities	27	5	Services
30	Renting of M&Eq and Other Business Activities	28	5	Services
32	Education	29	5	Services
33	Health and Social Work	30	5	Services
31	Public Admin and Defence; Compulsory Social Security			
34	Other Community, Social and Personal Services	31	5	Services
35	Private Households with Employed Persons			

Notes: The detailed sector aggregation follows that in Costinot and Rodríguez-Clare (2014). Trade elasticities are from Caliendo and Parro (2015).

Appendix 3 Additional welfare results

Table A7: Long-run Decomposition

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Annual shock				Cumulated shock			
	DTA & tariff split		Goods & services split		DTAs & tariffs		Goods & services split	
	DTA share	Tariff share	Goods share	Services share	DTA share	Tariff share	Goods share	Services share
AUS	47.26%	52.74%	60.55%	39.45%	48.54%	51.46%	62.17%	37.83%
AUT	57.96%	42.04%	59.19%	40.81%	60.95%	39.05%	60.95%	39.05%
BEL	58.96%	41.04%	57.49%	42.51%	61.54%	38.46%	59.68%	40.32%
BRA	51.66%	48.34%	51.17%	48.83%	52.00%	48.00%	52.00%	48.00%
CAN	43.04%	56.96%	57.93%	42.07%	42.96%	57.04%	58.45%	41.55%
CHN	16.51%	83.49%	84.18%	15.82%	15.37%	84.63%	85.50%	14.50%
DEU	56.69%	43.31%	55.86%	44.14%	59.40%	40.60%	57.33%	42.67%
DNK	53.73%	46.27%	58.84%	41.16%	55.71%	44.29%	60.93%	39.07%
ESP	58.46%	41.54%	55.23%	44.77%	61.63%	38.37%	56.60%	43.40%
FIN	55.62%	44.38%	58.79%	41.21%	58.70%	41.30%	60.17%	39.83%
FRA	55.46%	44.54%	55.69%	44.31%	58.14%	41.86%	56.73%	43.27%
GBR	54.20%	45.80%	55.47%	44.53%	56.54%	43.46%	56.54%	43.46%
GRC	52.26%	47.74%	64.98%	35.02%	55.56%	44.44%	67.46%	32.54%
HUN	65.38%	34.62%	75.17%	24.83%	68.64%	31.36%	78.00%	22.00%
IDN	48.14%	51.86%	68.27%	31.73%	51.23%	48.77%	71.78%	28.22%
IND	7.76%	92.24%	93.05%	6.95%	6.45%	93.55%	94.55%	5.45%
IRL	54.03%	45.97%	53.98%	46.02%	55.87%	44.13%	54.85%	45.15%
ITA	57.47%	42.53%	53.78%	46.22%	60.66%	39.34%	54.55%	45.45%
JPN	51.56%	48.44%	49.91%	50.09%	53.41%	46.59%	48.86%	51.14%
KOR	45.07%	54.93%	58.75%	41.25%	47.82%	52.18%	58.50%	41.50%
MEX	41.64%	58.36%	67.90%	32.10%	39.30%	60.70%	71.43%	28.57%
NLD	57.34%	42.66%	54.12%	45.88%	60.00%	40.00%	55.22%	44.78%
POL	59.99%	40.01%	76.00%	24.00%	64.16%	35.84%	78.47%	21.53%
PRT	64.31%	35.69%	54.48%	45.52%	68.26%	31.74%	56.29%	43.71%
ROU	44.20%	55.80%	79.94%	20.06%	47.06%	52.94%	83.23%	16.77%
RUS	50.32%	49.68%	52.25%	47.75%	49.70%	50.30%	53.76%	46.24%
SWE	54.74%	45.26%	56.66%	43.34%	57.21%	42.79%	57.92%	42.08%
TUR	56.20%	43.80%	58.51%	41.49%	57.14%	42.86%	58.71%	41.29%
TWN	46.51%	53.49%	54.47%	45.53%	45.68%	54.32%	55.67%	44.33%
USA	51.91%	48.09%	49.44%	50.56%	53.07%	46.93%	48.88%	51.12%
RoW	44.74%	55.26%	75.23%	24.77%	46.56%	53.44%	77.88%	22.12%
average	48.20%	51.80%	66.53%	33.47%	49.53%	50.47%	69.32%	30.68%

Notes: This table presents the decomposition of welfare effect of trade liberalization during 1995-2011 for each economy, using the simulation results that feed the estimated changes in trade costs according to Equation (2). The changes in trade costs consider contemporary, anticipation, and phase-in effects of trade agreements. Column 1-4 feed the estimated annual changes in trade costs to the model. Column 5-8 feed the cumulated annual changes in trade costs from 1995-2011 to the model and compute the equivalent variation induced by accumulated changes, assuming real consumptions grew linearly over time. Columns 1 and 2, and columns 5 and 6, feed the DTA and tariff shocks in isolation, respectively, and present results in terms of shares. Similarly, columns 3 and 4, and columns 7 and 8 decompose the effects into gains from trade liberalization in goods versus services sectors, respectively.