Numerical Methods for Ex Ante Policy Assessment of NTMs and the Impact of NTMs in Models of Firm Heterogeneity *

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Abstract

This report provides an overview of numerical methods for ex ante policy assessment of NTMs. We do this through a comprehensive overview of the ex ante policy assessments of the Transatlantic Trade and Investment Partnership (TTIP). In these studies most of the expected trade and welfare effects occur through changes in non-tariff measures (NTMs). We compare different methodological approaches to predicting the welfare effects of trade policy experiments. Methodologically the studies can be divided into those employing computable general equilibrium (CGE) models and structural gravity (SG) models. We compare and critically discuss differences in the estimated trade cost reductions and in the economic models employed, and how these can explain the relatively wide range of economic effects found in the different studies. The report also discusses the integration of firm theory with gravity estimation frameworks and the extension of the theoretical structure of CGE models with firms and NTMs.

Keywords: Ex ante trade policy experiments, non-tariff measures, computable general equilibrium models, structural gravity models, firm heterogeneity

JEL codes: F13, F14, F15

1 Introduction

Non-tariff measures play a dominant role in ex ante assessments of trade policies such as the introduction of free trade agreements (FTAs). Tariffs between most countries negotiating FTAs are already at a low level and so play a minor role. In the era of global value chains provisions on NTMs play a dominant role in so-called deep FTAs (Baldwin, Baldwin (2014)). Simultanously, there is increasing attention for the impact of non-tariff measures on the role of firms. In the first part of this report we provide an overview of numerical methods for ex ante policy assessment of NTMs. We do this through a comprehensive overview of the ex ante policy assessments the of Transatlantic Trade and Investment Partnership (TTIP). In these studies most of the expected trade and welfare effects occur through changes in non-tariff measures (NTMs). In the seconc part of the report we discuss the integration of firm theory with gravity estimation frameworks and the extension of the theoretical structure of CGE models with firms and NTMs.

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In particular we discuss calculation of ad valorem equivalents in models of firm heterogeneity and implement shocks to NTMs in these type of models.

Following the start of the negotiations on TTIP in 2013, a series of studies have been done to estimate the expected economic impact of TTIP on both regions. These studies can be split up into two types according to the methodology employed: Computational General Equilibrium (CGE) models and Structural Gravity (SG) models. Both studies concentrate, however, on the effect of an FTA between the transatlantic partners running through the reduction in NTMs. Until recently CGE models have been regarded as the standard economic instrument to analyse large multi-country trade policy agreements. CGE models are general equilibrium models calibrated to real-world data and used to determine the economic effects of policy changes. CGE-models are usually large-scale, complex models with many dimensions (countries, sectors, factors of production), which have been expanded over time to allow the analysis of detailed features of the economy that are of interest to policy-makers: i.e. how bilateral trade changes affect sectoral production, consumption, employment and broader macroeconomic outcomes: welfare, GDP, consumption per capita and public finances, among others.

The new class of structural gravity (SG) models, in contrast, is based on the literature providing micro-foundations for the gravity equation (Anderson and van Wincoop, 2003; Eaton and Kortum, 2002). These micro-founded gravity models can be employed to run counterfactual trade policy experiments and evaluate their welfare and GDP effects, besides their original aim of estimating bilateral trade flows (cf. Yotov et al., 2016). Structural gravity models are typically smaller and thus also contain fewer parameters. As a result all model parameters can be estimated structurally. In this context, structural estimation refers to the close link between theory and estimation, where the estimated equations are derived directly from theory and all the parameters of the model –i.e. trade elasticities, changes in non-tariff measures (NTMs) and other trade costs– are estimated employing the same database used for the simulations. To keep the models parsimonious, there is often only a single sector and many institutional details present in CGE models are omitted. Some consider this as an advantage: in parsimonious models it is easier to analyse and understand the effects of policy experiments. In this regard CGE models are often seen as a black box (see for example, Costinot and Rodríguez-Clare, 2013; Caliendo and Parro, 2015, for this line of reasoning). Others see the small scale of SG-models as a disadvantage: they cannot capture all the complexities involved in today's practice of trade policy.

CGE models are mostly used by trade policy researchers, whereas SG models are mainly employed by academic economists, although there is a tendency for CGE modellers to include the most recent developments in the academic trade literature and for SG modellers to extend their models with, for example, multiple sectors and multiple factors of production. These efforts have resulted in more recent hybrid analyses that mix both methodologies. In this approach, trade elasticities and other trade-specific parameters are structurally estimated following the SG methodology and these estimations are then embedded into a CGE/quantitative trade framework, where its more complex and detailed features provide a broad range of economic outcomes.

In the first part of this report we review, compare and assess the CGE- and SG-based studies on TTIP in order to draw conclusions about the expected economic effects of this trade agreement, focusing on the effects running through reductions in NTMs. The report serves three goals. First, it explores the differences between CGE-models and SG-models in international trade. Second, it provides a detailed comparison of the most influential studies on the economic effects of TTIP, in terms of trade cost reductions associated with TTIP and the economic models employed. Third, it evaluates the impact of different modelling features on the welfare effects of trade cost shocks associated with the introduction of a free trade agreement (FTA) like TTIP. As such, the report goes beyond a simple comparison of studies on TTIP by providing a detailed overview and critical discussion of the current approaches to measuring the expected economic welfare effects of trade policy experiments.

We select seven studies covering the different approaches used to evaluate the effects of TTIP. Table 1 compares these seven studies, evaluating them in terms of economic effects, expected reductions in trade costs ("TTIP-experiment") and the theoretical model employed. The differences between the expected trade cost reductions and between the theoretical models employed will be discussed and assessed into detail in the report. Throughout the report we focus on a broad definition of "welfare" as a means to summarise the macroeconomic effects of TTIP. In particular, we refer to welfare effects as the changes in real GDP or real income –depending on the variable that each study focusses on.[1] The predicted economic effects of TTIP range from a 0.3% real GDP increase for the USA from the CEPII study to a 13.4% real income increase from the study by Felbermayr et al. (2013). This is a relatively wide range of economic effects, which begs the question on why different quantitative trade methods yield diverging results.

We find that differences in the estimated trade costs reductions and in the economic models employed can explain the main discrepancies in welfare predictions that both classes of models make for TTIP. The economic modelling differences with the largest impact on the welfare effects of TTIP are: i. baseline calibration of trade costs; ii. the presence of intermediate linkages; iii. endogenous labour and capital accumulation; iv. the size of the employed trade elasticities; and v. the scope for substitution between value added and intermediates in production. Based on a comprehensive assessment of the assumed trade cost reductions and economic models of the different TTIP studies, we conclude that a reasonable range for the welfare gain is between 0.2% and 2%, depending on the economic model employed.

In the second part of this report we extend the standard tools in CGE-modelling with firm heterogeneity and conduct experiments with reductions in NTMs, both through reductions in iceberg trade costs and in fixed trade costs. The standard way to handle international trade in CGE models is with the Armington assumption, featuring constant elasticity of substitution (CES) preferences with love-of-variety between varieties from different sourcing countries. Although intra-industry trade can be modelled with the Armington assumption, products from each country are homogeneous and produced under perfect competition with this approach, which is unsatisfactory. Krugman (1980) and Ethier (1982) explain intra-industry trade in respectively final and intermediate goods combining love-of-variety in preferences, increasing returns to scale in production, and monopolistic competition as market structure. Preferences are characterized by love-of-variety between varieties produced by different firms. Intra-industry trade emerges naturally from the desire of consumers to buy as many different varieties and the benefits of sharing the fixed costs to develop new varieties through international trade in this model. An increase in the amount of inputs leads to a more than proportional increase in utility, because of love-of-variety. The Ethier-Krugman approach is also unsatisfactory, because of the assumption that all firms are identical. Melitz (2003) introduces firm heterogeneity in the Ethier-Krugman approach, modelling productivity (the inverse of marginal costs) as heterogeneous. So, firm heterogeneity adds realistic features like changes in productivity and the number of varieties. Firm heterogeneity also generates an additional welfare gain from trade, the reallocation of market shares from less productive firms producing for the domestic market to more productive exporting firms.

In this report we map out a parsimonious representation of Melitz-type firm heterogeneity with a Pareto productivity distribution enabling incorporation in multisector CGE models. In particular, we show that both the Ethier-Krugman and the Melitz model can be defined as an Armington model by generalizing the expressions for iceberg trade costs and by including

[1]Note that this is an aggregated welfare measure that does not account for any distributional effects. Thus, it implicitly assumes that the marginal utility of income is homogenous across all households. Although the distributional impact of trade is a growing public concern, none of the TTIP studies analysed here find significant negative inequality effects of the treaty. Therefore, we leave this topic out of our analysis.

Table 1: Comparison of TTIP studies

	CEPR study	CEPII study	Egger et al. 2015	Aichele et al. 2014	Felbermayr et al. 2015	Felbermayr et al. 2013	Carrere et al. 2015
Economic effects							
Main outcome variable[D]	GDP	GDP	real income	real income	real income	real income	real income[5]
EU	0.5	0.3	1.0	2.1	3.9	8.0[4]	0.17
USA	0.4	0.3	2.3	2.7	4.9	13.4	0.26
Model type:	CGE	CGE	CGE	SG	SG	SG	SG
TTIP-experiment							
NTM estimations:	bottom-up	bottom-up	top-down deep FTAs	top-down deep FTAs	top-down all FTAs	top-down all FTAs	top-down all FTAs
Percentage change iceberg trade costs[A]	-2.5	-7.1	-13.0	-13.2	-15.9	-16.2	-15.1
Spillover-effects[B]	yes	no[1]	no[1]	no[1]	no[1]	no	no
Theoretical model							
Baseline calibration to	actual shares	actual shares	actual shares	actual shares	fitted shares	fitted shares	actual shares
Intermediate linkages	yes	yes	yes	yes	no	no	yes
Multiple sectors	yes	yes	yes	yes	no	no	yes
Multiple prod. factors	yes	yes	yes	no	no	no	no
Preferences	non-HT[2]	non-HT	non-HT	HT	HT	HT	HT
Labour supply	fixed	fixed	fixed	fixed	fixed	fixed[3]	endogenous
Labour types	two	two	three	one	one	one	one
Market structure	large-group mon. comp.	nested mon. comp.	large-group mon. comp.	Eaton-Kortum perf. comp.	large-group mon. comp.	large-group mon. comp.	Eaton-Kortum perf. comp.
Endogenous capital	yes	yes	yes	no	no	no	no
Trade elasticity[C]	5.11	4	5.11	3.17	6.79	7	8

Notes: A. Overall trade-weighted average percentage iceberg trade cost reductions in main scenario, taken from Table 2. B. Direct and indirect spillovers to third countries. C. It is a unique value in single-sector models and a trade-weighted sectoral average in multi-sector models. D. Main economic outcome of each study, all in percentage changes. 1. Spillover effects only in alternative scenarios. 2. Non-HT: non-homothetic preferences. HT: homothetic preferences. 3. The study also contains an alternative model with endogenous labour supply, but the welfare results presented from the main scenario are based on the model with fixed labour supply. 4. Unweighted EU average. 5. This study also presents welfare effects with welfare defined as a weighted average of changes in real income and unemployment.

Sources: Own elaboration based on inputs from the referred studies.

supply and demand shifter in the Melitz model. The Ethier-Krugman model features a supply shifter which is a function of the number of input bundles leading to so-called variety scaling (Francois (1998)). An increase in the number of input bundles in a sector reduces the average sectoral price and raises effective output. This is driven by the presence of love-of-variety in preferences combined with fixed costs in production. A larger number of input bundles raises the number of varieties produced, thus reducing the average sectoral price.

Variety scaling also props up in the Melitz model, but on top of that the supply shifter (and thus the average sectoral price) is a function of the price of input bundles as well. The reason is that both the extensive and compositional margin are affected by the price of input bundles. With a lower price of input bundles more firms can sell profitably to the different destination markets generating a positive effect through the extensive margin (more varieties) and a negative effect through the compositional margin (lower average productivity because of the survival of the least productive firms as well).[2] For the same reason there is a demand

[2] Head and Mayer (2015) introduced the distinction between the intensive, extensive, and compositional margin in the context of the gravity model under international trade.

shifter in the Melitz model: in a larger market with a higher price index more firms can survive, raising the beneficial extensive margin but also the harmful compositional margin. Generalized iceberg trade costs are a function of fixed and iceberg trade costs and of tariffs. We show theoretically that the Ethier-Krugman model is a special, limiting case of the Melitz model for the firm size distribution becoming granular. Granularity corresponds with a trade elasticity in Melitz equal to the substitution elasticity minus one. The reason for the nesting is that under granularity the destination-varying component of the extensive margin cancels out against the compositional margin leaving only the intensive margin and the number of entrants-component of the extensive margin, the two channels also operative in Ethier-Krugman.

The trade structure of the firm heterogeneity model is calibrated based on two estimable parameters, the tariff or trade elasticity and the shape parameter of the firm size distribution. These two empirically identifiable parameters determine the substitution elasticity and the shape parameter of the Pareto productivity distribution. Separate values for fixed and iceberg trade costs are not needed in our framework and the two types of trade costs are calibrated jointly based on observed import shares. In the GEMPACK implementation explicit values of trade costs are not needed. Their implicit values serve to set baseline import shares equal to actual shares. In the calibration part of the report we also discuss the calculation of ad valorem equivalents (AVEs) of NTMs under the three trade structures. In particular, we point out how coefficients on trade cost measures like NTM-dummies in a gravity equation can be mapped into AVEs. We outline as well how NTM-type trade cost measures can be mapped into fixed cost equivalents, thus enabling us to evaluate the impact of changes in NTMs running through changes in fixed trade costs.

We conduct counterfactual experiments on reductions in NTMs with our model in a medium-sized model with 11 regions, 11 sectors, and 6 factors of production. We run three sets of experiments with reductions in NTMs operationalized through reductions in iceberg and fixed trade costs comparing the three trade structures. First, a uniform identical reduction in iceberg trade costs in the different models, and second and third an identical change in a NTM dummy variable in the gravity equation implied by the three trade models for the model calibrated to respectively the tariff and trade elasticity. For all three experiments the reduction in NTM-related trade costs generates the largest effects in the Melitz model, followed by the Ethier-Krugman and Armington model. However, the differences are relatively modest with the Melitz model displaying maximum 10% larger welfare effects (measured as the change in world equivalent variation) of a 2% reduction in iceberg trade costs than the Armington model. The difference in welfare effects is only about 2% between Melitz and Ethier-Krugman. The differences are larger for uniform reductions in an NTM dummy variable. The welfare decomposition shows that the net contribution of the new margins due to changes in average imported and domestic productivity and imported and domestic number of varieties is relatively modest.

We view our approach as complementary to earlier work in both the CGE- and NQT-literature. In particular, our approach contributes to the existing literature in the following three ways. First, we present a parsimonious and intuitive way to include firm heterogeneity in a CGE-model going along with straightforward estimation of the model parameters. By adding demand, supply, and trade cost shifters to the existing trade structure used in most CGE-models (Armington) we propose an intuitive and flexible way to switch between the different trade structures.[3] Second, with our framework we are able to conduct experiments with the Melitz and Ethier-Krugman structures in a CGE model with intermediate linkages and a large number of countries and sectors. In this report we present simulations with 11 regions, 11 sectors, and 6 factor of production. Third, we introduce additional features in the model like a

[3]Dixon et al. (2016) also introduce an encompassing model for the three structures, but do not write the Melitz model as an Armington structure with only demand and supply shifters. They include additional equations in the Melitz structure to solve for example for the number of varieties and the average poductivity, following mostly the set of equilibrium equations in Balistreri and Rutherford (2011).

decomposition of changes in trade values into three margins, a generalization of the CES utility function to separate the substitution elasticity and the strength of love-of-variety, a welfare decomposition, and equivalent shocks across the three models in estimated NTM-coefficients from a gravity equation.

We start in Section 2 with a general comparison of SG- and CGE-models. In Section 3 we compare the predicted reductions in trade costs, concentrating on the reduction in non-tariff measures (NTMs).[4] In Section 4 we present the main differences in the economic models employed and discuss the expected impact of the most important differences between the models, such as the presence of intermediate linkages, baseline calibration and the way the labour market is modelled. Section 5 then attempts to explain the differences in economics effects based on the differences in model features and the predicted reductions in trade costs. This section also contains a synthesis of the different studies based on our own judgement of these studies. Section 6 outlines the theoretical structure of the CGE-model with firm heterogeneity and points out how the three different trade structures can be modelled within the existing trade structure of the CGE-model GTAP. Section 7 discusses calibration of the parameters of the model and estimation of the ad valorem equivalents of NTMs under firm heterogeneity. Section 8 presents the results of counterfactual experiments. In Section 9 we conclude with a summary of the expected economic effects of NTMs in TTIP and the impact of modelling firms in quantitative trade models on the effect of NTMs. We also give suggestions for future research on the economic effects of NTMs in FTAs like TTIP.

2 General differences between SG and CGE models

There are strong similarities between CGE models (see Dixon and Jorgenson, 2012, for an overview) and the recent class of SG models (cf. Arkolakis et al., 2012; Costinot and Rodríguez-Clare, 2013). Both strands of quantitative trade models are micro-founded and use theory in order to derive quantitative results. Hence, both analytical frameworks can explore the magnitude of particular economic effects using detailed trade data, and they can also assess the nature of the relationship between two economic variables –e.g. is it monotone or not (Costinot and Rodríguez-Clare, 2013). There are, nevertheless, also important differences between both analytical frameworks. We discuss three of them.

First, SG-models aim to estimate all the parameters of the model structurally, whereas parameters in CGE models are often taken from other studies in the literature. The estimated parameters consist both of behavioural parameters like the substitution elasticity and the expected changes in technology or trade costs as a result of a policy experiment.

Second, the size and scope of the models employed to run counterfactuals differs between the two approaches. CGE-models include a large number of features –like intermediate linkages, multiple sectors, multiple factors of production, non-homothetic preferences, endogenous capital formation, imperfect competition, international transport margins, detailed policies like tariffs and export subsidies– which are often omitted in the SG-models. Obviously, these first two differences are related, since including a large number of features in the model increases the number of parameters, which makes it less likely that all parameters can be estimated. Proponents of CGE models argue that many effects of trade policy changes are omitted in small-scale SG-models by not including detailed modelling features. Proponents of SG models argue that these omitted effects are of second-order importance and that by keeping the model parsimonious, all parameters can be estimated structurally.

The single-sector studies on TTIP based on the SG-approach (Felbermayr et al., 2013, 2015) contain only one behavioural parameter, the elasticity of trade values with respect to

[4] We concentrate on the effects through NTMs and leave the effects of tariff reductions mostly aside. The reason is twofold. First, tariff effects are very limited given that existing tariff levels are relatively low between the TTIP partners. Second, the studies do not differ much in the impact of TTIP through tariff reductions.

trade costs.[5] The CGE studies working with non-homothetic preferences, multiple sectors and multiple factors instead contain many more parameters and many of these parameters are not estimated structurally –i.e. estimated from the same data as used for the simulations– but are taken from external sources. CGE-models are oftentimes criticised for this practice. We observe, nonetheless, that the parsimonious models with a small number of structural parameters often do not structurally estimate all parameters either, but implicitly assume values for many of the parameters featuring in the more extensive CGE models. For example, multi-sector SG models usually work with Cobb-Douglas preferences for goods between different sectors (compared to non-homothetic preferences in CGE-models). As such the SG-models are implicitly assuming that the substitution elasticity between all goods is one and the income elasticity of all goods is also one.

Third, calibration of the baseline differs sharply between CGE- and SG-models. The baseline is the outcome of the model without imposing policy experiments and serves as the starting point for counterfactual policy experiments. In CGE-models baseline shares are identical to the shares used to calibrate the model by choosing appropriate values for the so-called shift parameters of the model. For example, Armington shifters are set at a value such that baseline import shares are identical to the import shares in the data. In SG-models, by contrast, baseline iceberg trade costs are based on the estimated gravity equation. Iceberg trade costs are equal to the fitted –or phrased differently, predicted– values of the estimated model. This implies that baseline import shares can deviate from actual import shares in the data. On the one hand, a disadvantage of the CGE-practice of calibrating baseline shares to actual shares is that actual shares in a particular year might be affected by outliers. For example shares might be calibrated to the year 2008 when the financial crisis happened and thus, be strongly affected by outliers. On the other hand, baseline import shares might be far away from actual import shares in the SG-approach if the gravity equation suffers from misspecification. This seems to be especially problematic for the expenditure share on domestic goods in gravity models that do not include domestic flows. The impact of calibration of baseline trade costs will be further discussed below in Subsection 4.1 on modelling features and in the comparison of model outcomes in Section 5. In the latter we will argue that in some of the SG-models baseline domestic shares deviate significantly from the actual domestic shares, which has important implications for the predicted welfare effects.

3 Differences between the reductions in NTMs

An important difference between the TTIP studies is the counterfactual trade policy experiment associated with TTIP. To calculate the effect of TTIP researchers have to identify how TTIP will change the costs of trading goods internationally. In the different studies two types of reductions in NTMs are identified: first, a reduction in NTMs between the EU and the US; and second, a reduction in NTMs between the EU and the US with third countries –i.e. the so-called spillover effects.[6]

[5] However, it is remarkable that Felbermayr et al. (2013) and Felbermayr et al. (2015) do not estimate structurally their only behavioural parameter, the trade elasticity, but pick a value for the trade elasticity from the literature. On the other hand, Caron et al. (2014) is an example of a multi-sector SG model where all parameters are estimated structurally. They study the relation between the income elasticity and factor intensity of goods in a multi-sector model with non-homothetic preferences using the GTAP database.

[6] The focus of this report is NTMs, so tariffs are omitted. Tariff reductions also play a very minor role in the total effect of TTIP, since initial tariffs are low between the EU and the USA. All CGE-based models account separately for the reductions in tariffs and NTMs. On the other hand, most SG-based approaches account for the overall reduction in iceberg trade costs, which capture the trade costs reductions associated with TTIP without distinguishing between tariffs and NTMs.

3.1 NTM reductions

As pointed out above, since the current tariff levels between the US and the EU are already relatively low, the largest impact of TTIP is expected to come from changes in NTMs. Thus, the estimation of NTMs becomes a critical element for assessing the potential economic effects of TTIP properly.[7] Roughly speaking we can distinguish between two approaches to estimating the expected reductions in NTMs as a result of TTIP:

1. Bottom-up approach. In the bottom-up approach the size of NTMs is estimated at the sector-level using detailed micro data (firm-level surveys and product-level data, sometimes in combination with expert opinion), followed by a projection of the reduction in the NTMs as a result of TTIP. Francois et al. (2013) follow this approach with the size of NTMs inferred from business surveys with about 5,500 data points and this information is then employed in a gravity framework to estimate sector-specific NTMs. Fontagné et al. (2013) also follow a bottom up approach with the level of NTMs estimated at the product level based on the UNCTAD-TRAINS database for NTMs in goods and their own CEPII estimates for NTMs in services (Fontagné et al., 2011).

2. Top-down approach. Instead of first determining the level of NTMs and then projecting the reduction resulting from the FTA, the top-own approach infers the reduction in trade costs as a result of the FTA directly from gravity estimations. A variable for the presence of an FTA is included in a gravity equation in addition to the usual gravity variables: distance, tariffs, importer and exporter fixed effects and additional control variables (e.g. common border, common language and colonial past). The FTA-coefficient indicates by how much FTAs have increased trade in the past and can thus be used to determine the percentage change reduction in iceberg trade costs as a result of the FTA. The studies differ with respect to the way the gravity equation is estimated. Some studies (Felbermayr et al., 2015, 2013; Carrere et al., 2015) model the effect of TTIP by means of a simple 0-1 FTA dummy. As such TTIP is expected to generate the same trade cost reduction between EU countries and the US as FTAs have done on average in the past. Egger et al. (2015a) and Aichele et al. (2014a) instead take into account the depth of an FTA and model TTIP as the move from no FTA to a deep FTA.

To make the TTIP experiment comparable across studies we report the iceberg trade cost reductions as a result of TTIP in Table 2.[8] We find that there are significant differences in the trade cost estimations, ranging from 2.5% reductions in Francois et al. (2013) to 16.2% in Felbermayr et al. (2013). In general, the magnitude of the trade cost estimations is associated with the particular methodology employed: the studies using the bottom-up approach estimate smaller trade cost reductions than the studies using the top-down approaches. As we show below, these differences in the estimations of how much TTIP will reduce the bilateral trade costs between the US and the EU, is one of the main determinants to explain the different outcomes between studies.

3.2 Spillover effects

Finally, some studies also assume that if TTIP generates a new multi-lateral regulatory framework (i.e. a global regulatory standard), then TTIP could also create positive trade spillovers to/from third-countries. This concept of spillover effects was first employed in the CEPR study

[7] A detailed explanation of how NTMs are estimated in each study is provided in Bekkers and Rojas-Romagosa (2017). This study, in addition, also evaluates and compares the different estimation results.

[8] Iceberg trade costs are defined as one plus the ad valorem equivalent and measure the factor by which the price of a good traded between two countries rises. Bekkers and Rojas-Romagosa (2017) discusses into detail how reductions in iceberg trade costs can be determined in the different studies.

Table 2: TTIP experiment, percentage changes in iceberg trade costs

	EU	**USA**	**Both regions**
CEPR study	-2.3	-2.8	-2.5
Egger et al., 2015	-12.4	-13.6	-13.0
CEPII study	-6.5	-7.7	-7.1
Aichele et al., 2014	-12.7	-13.8	-13.2
Felbermayr et al., 2013	-16.2	-16.2	-16.2
Felbermayr et al., 2015	-15.9	-15.9	-15.9
Carrere, 2015	-15.1	-15.1	-15.1

Sources: Own estimations based on NTMs and trade cost reductions estimates are trade-weighted averages taken from the referred studies and using bilateral sector-specific US-EU trade data from the GTAP-9 database.

(Francois et al., 2013), where they distinguish between direct and indirect spillovers. Direct spillovers occur when third countries find it less-costly to export to the EU and the US as a result of TTIP creating a global regulatory standard. Indirect spillovers take place when third countries partially adopt these new global harmonised standards, resulting in lower trade costs between third-countries and for exports from the EU and US to third countries.

The most notable effect of including these spillover effects is that negative trade diversion effects on third countries become smaller, and also that –through the reductions of trade costs from the EU-US to third countries– both regions will also have larger economic gains. However, only Francois et al. (2013) include spillover effects in their main simulations, and their results only decrease slightly when they use an alternative scenario without the spillovers: GDP gains in the EU are reduced from 0.5 to 0.4% and from 0.4 to 0.3% in the US. Taking account of the inclusion of spillovers makes the results in the CEPR and CEPII studies closer to each other, but they do not explain the large differences between the CEPR study and those from Egger et al. (2015a), Aichele et al. (2014a) and Felbermayr et al. (2015).[9]

4 Differences between the theoretical models

In this section we map out what we consider to be the ten main differences between the theoretical models employed in each study. Table 1 already gave an overview of the way the different papers model these ten features: i. calibration of baseline trade costs and import shares; ii. the presence of intermediate linkages; iii. multiple sectors; iv. multiple factors of production; v. non-homothetic preferences; vi. the treatment of capital; vii. the treatment of labour; viii. the size of trade elasticities; ix. nested versus non-nested import demand; and x. market structure. In this section we first explore the impact of including these different elements on the expected welfare gains. We do so by using insights from the literature and presenting simulation results with both a simple single sector model as in the SG-studies on TTIP and a flexible CGE-model. In subsection 4.2 we describe the theoretical structures of the different models in detail by discussing both the ten features mentioned above and other features specific to each of the models.

[9] In Bekkers and Rojas-Romagosa (2017) we analyse the particular manner in which spillovers are modelled in each of the studies and we also compare the advantages and disadvantages of each approach.

4.1 Modelling features

In this subsection we explore the impact of each of the ten modelling features on the welfare effects of trade cost shocks.[10] To do so we use two models.

- First, a flexible CGE model in the spirit of the standard GTAP model but with additional features such as imperfect competition and endogenous capital accumulation and labour supply. The model is calibrated to GTAP9 data from 2011, aggregated to 16 regions, 17 sectors and 6 production factors. The baseline model features a representative agent demanding government goods, private goods and savings, intermediate linkages, trade modelled with Armington non-nested preferences, investment flows between countries and imperfect mobility across sectors of all factors of production (except for capital, which is fully mobile).[11][12]
- Second, a single-sector trade model without intermediate linkages with Armington preferences as in Anderson and van Wincoop (2003), which resembles the one-sector models employed in the SG-studies on TTIP, but calibrated to the GTAP9 data with 121 countries.[13] This model is described in detail in Appendix A.[14]

We evaluate the impact of each of the modelling features below by running 20 counterfactual simulations featuring reductions in iceberg trade costs by 1% to 20% between the EU and the US. We report the percentage change in utility in the EU, while changes in the US display similar patterns. In this sense, we equate utility changes to welfare changes –as defined in the rest of the report– since there is a strong correlation between changes in utility and changes in other welfare definitions, such as real income and real GDP.[15] Moreover, throughout this section we use both definitions interchangeably.

Figures 1, 2 and 3 display the results of our simulations, showing the percentage change in welfare for the different models as a function of the reduction in iceberg trade costs. To see more into detail how large the differences in welfare effects are, Table 3 displays the percentage change in welfare of a 13% iceberg trade cost reduction (i.e. the values used in Egger et al., 2015a).

1. In CGE-models and also in the quantitative trade models employing exact hat algebra (EHA)[16] to solve for counterfactuals, baseline import and export shares are equal to actual

[10]As explained above, we focus exclusively on welfare, defined as real GDP or real income, since these are reported in all studies.

[11]We refer the reader to Hertel and Tsigas (1997), Hertel (2013a) and Bekkers et al. (2017b) for a detailed description of the model. There are two differences between the model in Bekkers et al. (2017b) and our baseline model. First, in our baseline simulations both labour and capital are exogenous and second, import demand is Armington instead of Eaton-Kortum. The parameter values are as in Bekkers et al. (2017b).

[12]The trade-weighted average trade elasticity is 8.56 and based on the estimated tariff elasticities in Bekkers et al. (2017b).

[13]In a single sector setting without extensive margin and a fixed amount of inputs (labour) the effects of a reduction in iceberg trade costs are identical to the effects in a Krugman-type model as used by Felbermayr et al. (2013) and Felbermayr et al. (2015). In addition, we calibrate the model to the same data as used for the flexible CGE-model, but with values aggregated to one sector and one factor of production.

[14]Following the single-sector TTIP work in Felbermayr et al. (2015), the trade elasticity is set equal to 7.

[15]In the more concise SG-models changes in utility are equal to changes in real income, which is also equal to the real wage, given that there is only one factor of production and given the absence of trade imbalances and/or assuming that trade balances stay constant.

[16]Traditional hat-algebra consists of log-differentiating (also called hat-differentiating because of the use of the hat-symbol) a system of equations to find the relation between variables in relative changes. Traditional hat-algebra involves an approximation of the original system of equations when changes are non-marginal. Exact hat algebra calculates the ratio of new to old equilibrium values of the endogenous variables. As such the exact effect of a change in exogenous variables on endogenous variables can be determined. See for more discussion of solution methods under the different methods Bekkers et al. (2017a).

shares in the data. In SG-models instead, baseline trade costs are based on the fitted trade costs implying that baseline shares are equal to the fitted import shares implied by the gravity estimation. The difference between the two approaches can be illustrated by writing down the following empirical gravity equation:

$$V_{ij} = \exp\left(T_{ij} + X_i + M_j\right)\varepsilon_{ij} \tag{1}$$

V_{ij} is the value of trade from i to j, X_i and M_j are exporter and importer fixed effects, T_{ij} is a function of the standard bilateral observable variables, such as distance and dummies for contiguity, common colony and the presence of an FTA, while ε_{ij} is the error term. In the SG approach baseline trade costs are calibrated to the fitted trade costs of an estimated gravity equation, $\widehat{T_{ij}}$. This implies that baseline import and export shares with respect to E_j (expenditure in country j) are equal to the predicted or fitted shares of the gravity estimation: $\frac{\widehat{V_{ij}}}{E_j}$, where $\widehat{V_{ij}} = \exp\left(\widehat{T_{ij}} + \widehat{X_i} + \widehat{M_j}\right)$ are the predicted trade flows from econometrically estimating equation (1). On the other hand, in CGE-models and models employing EHA, baseline import and export shares are equal to actual shares: $\frac{V_{ij}}{E_j}$. Therefore, the difference between the two approaches is whether the error term, ε_{ij}, is taken into account or not. If the gravity model delivers a good fit, the two methods will not lead to very different outcomes. If instead the gravity model suffers from misspecification, ε_{ij} could be large and neglecting it could have a large impact on the estimations.

We compare the two approaches to the baseline calibration using the single sector model without intermediate linkages, with a trade elasticity of 7 as in the study by Felbermayr et al. (2015). Figure 1 shows the welfare effects with four different calibrations, one to the actual shares and three with calibrations using the fitted shares: first, employing only international trade flows and no domestic flows and calibrating domestic trade costs as the fitted trade costs from the gravity equation (i.e. specification 1 in Figure 1); second, employing only international trade flows and no domestic flows and fixing domestic trade costs at zero (specification 2); and third, including also domestic trade flows (specification 3). Figure 1 shows that the different calibration methods generate very different results. With calibration to actual shares the welfare effects of a reduction of about 14% (e.g. the reduction in Felbermayr et al., 2015) generates a welfare gain of about 0.45%. The first calibration using fitted shares without domestic trade generates an effect that is about ten times larger, close to the welfare effects found in Felbermayr et al. (2015). In the second calibration that fixes domestic trade costs to zero, the welfare effects are reduced by about half. Finally, the third calibration based on gravity estimation including domestic trade flows makes the welfare effects smaller than in the calibration based on actual shares. The reason for these relatively large differences is that baseline import and export shares vary widely across the different methods and that these shares determine the welfare effects of a counterfactual experiment, as discussed in detail in Bekkers et al. (2017a). In particular, the calibration without domestic trade flows overstates the trade shares relative to the domestic shares and thus also overstates the welfare effects. Recent work quantifying the welfare effects of trade policy experiments with SG-models, proposes to include both domestic trade flows and pairwise fixed effects in the gravity estimation based on panel data, and this makes the difference between actual and fitted shares relatively small (Yotov et al., 2016). However, if the model is estimated with a cross-section of trade data, then pairwise fixed effects imply that fitted shares are equal to actual shares and CGE- and SG-baseline calibration would thus be identical.[17] In all the simulations that follow, to sterilise the impact of differences in baseline calibration, the baselines in the SG-model are calibrated to actual shares, as in the flexible CGE-model.

[17] Bekkers et al. (2017a) provides a more in-depth comparison of the two calibration methods, to fitted and to

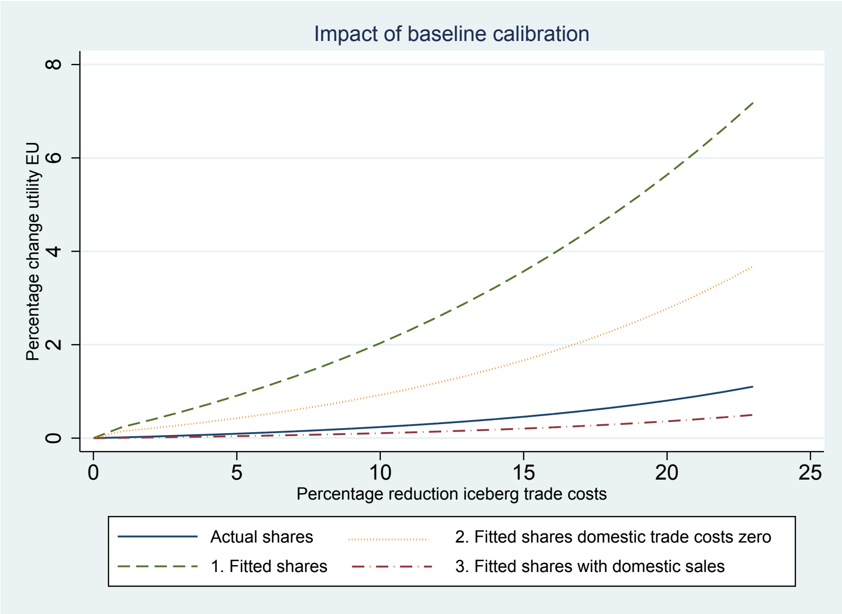

Figure 1: Impact of different calibrations of baseline trade costs on the welfare gains from trade cost reductions between TTIP partners

Notes: Specification (1.) employs only international trade flows and no domestic flows and calibrates domestic trade costs as the fitted trade costs from the gravity equation; Specification (2.) employs only international trade flows and fixes domestic iceberg trade costs at one (so trade costs are zero); Specification (3.) also includes domestic trade flows and a dummy for domestic trade flows. Source: Own calculations with single sector model as described in the text.

2. Intermediate linkages. Arkolakis et al. (2012) show theoretically that the welfare gains from openness get amplified when accounting for intermediate linkages. The reason is simple: lower trade costs make both final goods and intermediates cheaper and the latter makes price reductions of final goods even larger, thus generating a multiplier effect. We evaluate these effects with the single sector model by adding intermediate linkages to that model.[18] Figure 2 (panel a) shows that including intermediate linkages more than doubles the welfare effects for the EU of the TTIP experiment. Table 3 shows that the increase in welfare rises from 0.34% to 0.83% when applying a 13% trade cost reduction.

3. Multiple sectors. Ossa (2015) shows that the welfare gains from trade are larger in a setting with multiple sectors in comparison to a single-sector setting when trade elasticities differ across sectors. The reason is that the gains from trade in sectors with a low trade elasticity are very large. In an Armington setting the trade elasticity is equal to the substitution elasticity minus one, so a low trade elasticity corresponds with a low substitution elasticity and thus, a strong love of variety. The possibility to import in sectors with low substitution elasticities creates large gains. On the other hand, welfare gains are smaller in a single sector setting where the trade elasticity is an average across all sectors. In Figure 2 (panel b) we compare the baseline flexible CGE-model with 17 sectors (Line "1. Baseline ") and the flexible CGE-model with just one sector (Line "2. Single sector ") with the SG-type single sector model with intermediate linkages (Line "3. One sector").

   The figure shows that the welfare effects are almost identical under multiple and single

actual shares, also evaluating the potential advantages of calibration to fitted shares of being able to account for measurement error and random variation in trade flows.

[18]This is done by making gross output a Cobb-Douglas composite of intermediate inputs and factor inputs, while intermediate input bundles are identical to final consumption bundles as is standard in SG-models and models employing EHA, which include intermediate linkages. The equilibrium equations of the model are described in Appendix A.

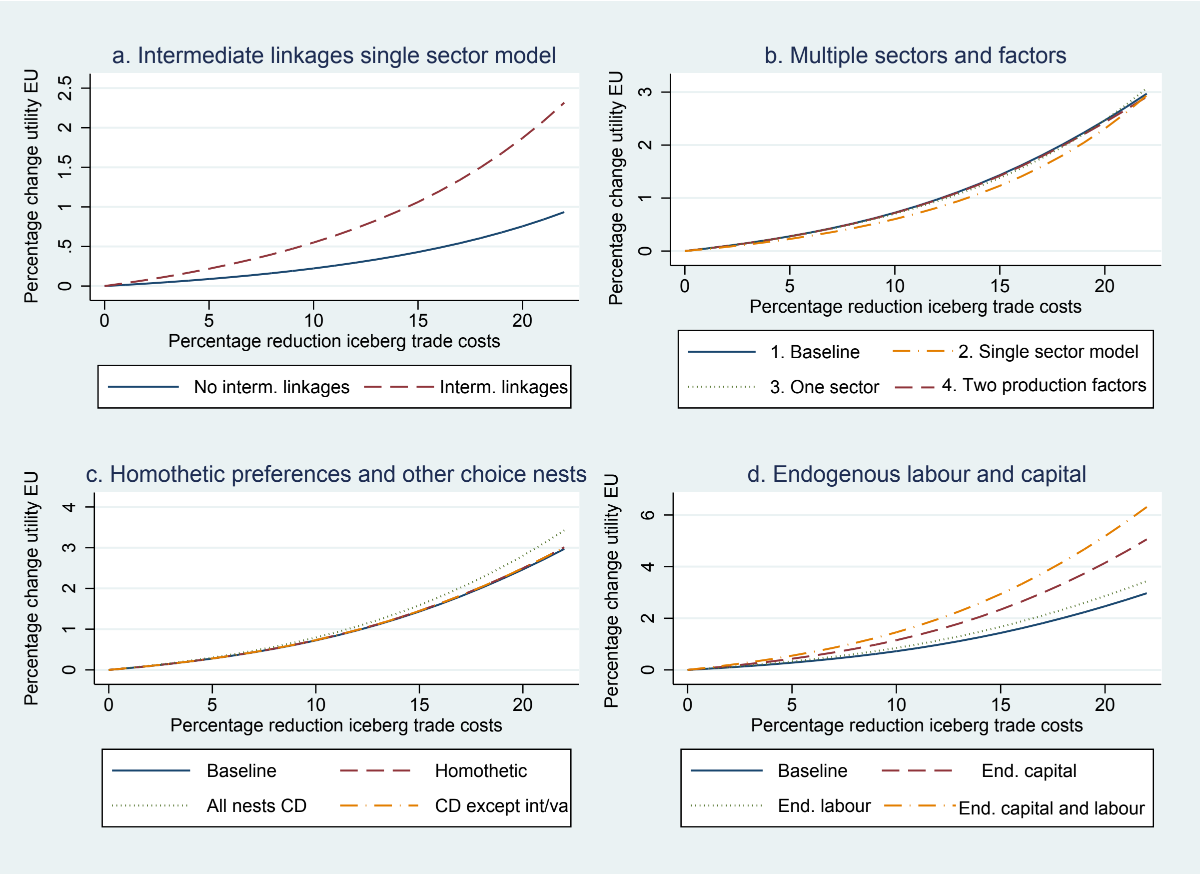

Figure 2: Impact of different modelling features on the welfare gains from trade cost reductions between TTIP partners

Source: Own calculations with flexible CGE-model as described in Hertel and Tsigas (1997), Hertel (2013a), and Bekkers et al. (2017b) and with single sector model as described in the text. Panel (a) is based on the single sector model, panel (b) on both the flexible CGE-model and single sector model and panel (c) and (d) on the flexible CGE-model

sectors. We can reconcile our findings with those in Ossa (2015) from the fact that he only addresses the welfare gains from trade and not from reductions in trade costs, which are the focus in the studies on TTIP.[19] The figure also shows that the simple single sector model with intermediate linkages generates very similar welfare effects as the multi-sector CGE model.[20]

4. Multiple factors of production. Costinot and Rodríguez-Clare (2013) argue that the inclusion of multiple factors of production does not have a large impact on the welfare gains from trade cost experiments. In Figure 2 (panel b) we confirm this point and show that moving from the baseline with six factors (Line "1. Baseline ") to a model with two factors of production (Line "4. Two production factors") has very little impact on the welfare effects of trade cost reductions. It seems that factor abundance differences between the US and the EU are relatively small and this leaves little scope for increased specialisation

[19]Moreover, Costinot and Rodríguez-Clare (2013) point out that the large welfare gains with multiple sectors hinges on a Cobb-Douglas specification for preferences across sectors. With a larger substitution elasticity between sectors, it is easier for consumers to substitute away from sectors without imports and low substitution elasticities.

[20]To compare the two models, the trade elasticity is set identical in the single sector variant of the flexible CGE-model and in the simple single sector model, at 8.5. This number is the trade weighted average generated by aggregating the 17 sector data to single sector data. In Figure 1 comparing baseline calibration methods, we used a trade elasticity of 7, following Felbermayr et al. (2015).

in settings with more factors of production.[21]

Table 3: The effect of a 13% reduction in iceberg trade costs between the EU and the USA on the percentage change in utility in the EU

Description	Model type	Percentage change utility EU
2. Intermediate linkages		
Single sector, no intermediate linkages	SG	0.335
Single sector, with intermediate linkages	SG	0.829
Baseline flexible CGE model	CGE	1.113
3. Multiple sectors		
One sector model	CGE	1.072
Single sector, with intermediate linkages and trade elasticity equal to 8.56	SG	0.940
4. Multiple factors		
Model with two factors of production	CGE	1.103
5. Non-homothetic preferences and Cobb-Douglas nests		
Homothetic preferences private demand	CGE	1.124
All nests Cobb-Douglas	CGE	1.226
All nests Cobb-Douglas, except for choice between value added and intermediates	CGE	1.124
6. Treatment of capital		
Endogenous capital	CGE	1.794
7. Treatment of labour		
Endogenous labour	CGE	1.300
Endogenous capital and labour	CGE	2.263
8. Size of trade elasticities		
Trade elasticity equal to 3	CGE	0.676
Trade elasticity equal to 5	CGE	0.777
Trade elasticity equal to 7	CGE	0.915
9. Nested import demand		
Nested import demand	CGE	0.865
Non-nested import demand	CGE	0.964
10. Market structure		
Armington trade structure	CGE	0.839
Melitz trade structure	CGE	0.902
Ethier-Krugman trade structure	CGE	0.892
Armington trade structure with endogenous labour	CGE	0.983
Ethier-Krugman trade structure with endogenous labour	CGE	1.161
Melitz trade structure with endogenous labour	CGE	1.231

Sources: Own estimations based on flexible CGE model and single sector SG model. The Armington, Melitz and Ethier-Krugman model are based on an aggregation with 11 countries and 11 sectors. The other CGE-simulations are based on the sectoral aggregation used in Bekkers et al. (2017b) with 17 sectors and 16 aggregated regions. The table displays the change in utility in the EU of a 13% change in iceberg trade costs between the EU and the USA organised by differences in modelling features in the main text.

5. Non-homothetic preferences and Cobb-Douglas nests. With non-homothetic preferences

[21] A fairly common feature of CGE models is that factors are (partially) immobile across sectors and that some factors are linked to specific sectors. For instance, in the CEPR study the production factors land and natural resources are linked to agriculture and primary activities and thus, only partially mobile between these sectors. This makes it more costly to reallocate resources between sectors. As a result the impact of changes in trade costs will be larger than in a setting where production factors can move freely. However, in simulations available upon request, we show that moving towards full mobility of the three types of labour in the GTAP9 database has little impact on the welfare effects of the TTIP experiment.

one allows for changing spending shares on different goods (food and services for example) as countries become richer. Given that TTIP is a trade agreement between developed countries, it is not expected that non-homothetic preferences will have a strong impact on the welfare effects. This prior is confirmed in Figure 2 (panel c). Moving from the baseline with non-homothetic preferences towards homothetic preferences with fixed spending shares has little impact on the welfare effects of TTIP.[22]

The employed CGE-model features two other elasticity parameter choices over the nested functions: between intermediates and value added, and between different factors of production. Figure 2 (panel c), shows that modelling both choices in the model as Cobb-Douglas (fixed shares) significantly raises the welfare effects of the TTIP experiment. Moreover, this increase is mainly driven by the parameter choice for the nest between intermediates and value added. When this parameter is set to zero (i.e. Leontief technology with no scope for substitution and fixed volume shares) the welfare results are very similar with the baseline, but when it is set to one (Cobb-Douglas technology with fixed value shares), the welfare effects are higher. This is a result of the broader substitution possibilities that come with lower prices of imported intermediates when trade costs are reduced. Table 3 shows that the utility increase in the EU of the 13% decrease in iceberg trade costs rises by about 10% from 1.12% to 1.23% when making also the choice between intermediates and value added Cobb-Douglas.

6. Treatment of capital. Most CGE models include capital as a production factor, investment as a tradable good, and then model the relation between investment and capital. Two modelling features regarding capital are specially important. First, in the standard GTAP model changes in investment as a result of a trade experiment only affect the flow of investment goods and do not affect the amount of capital. Phrased differently, capital does not become "online" –i.e. as capital stock that is actually used in production. In Francois et al. (2013) and Egger et al. (2015a) instead, changes in investment do affect the capital stock used in production to mimic a long run approach where investment flows are translated into capital, and this process generates an endogenous capital accumulation mechanism in the model. As pointed out in Francois et al. (1996) this feature significantly raises the welfare effects of trade liberalisation. Second, in the standard GTAP model capital is not fully mobile across countries and rates of return are not equalised, but capital tends to flow to countries with higher rates of return. In Francois et al. (2013) and Egger et al. (2015a), instead, rates of return are equalised. In the multi-period model employed by Fontagné et al. (2013) investment also affects the amount of capital employed in production and investment flows to regions with higher rates of return.

   In Figure 2 (panel d) we show that moving towards endogenous capital accumulation raises the welfare gains of the TTIP experiment considerably.[23] The scale of the percentage change in welfare is different in panel (d) from the other panels, indicating that endogenous factor supply has a large impact on the welfare effects. In Table 3 we see that the welfare effect rises from 1.11% to 1.79% when moving from the baseline CGE model to the model with endogenous capital.

7. Treatment of labour. All studies except for Carrere et al. (2015) work with a fixed labour supply. Endogenous labour supply can be modelled using equilibrium models of unemployment (as in Carrere et al., 2015) and/or by a labour-leisure decision (see for example Bekkers et al., 2017b). Figure 2 (panel d) shows that with an endogenous labour supply

[22] Non-homothetic preferences can be highly relevant for studying the welfare effects of sectoral liberalisation in developing versus developed countries. For example, lower food prices as a result of agricultural liberalisation has a stronger impact on poor countries, which spend a larger share of their income on food.

[23] Endogenous capital accumulation is modelled as in Francois et al. (2013), i.e. changes in investment affect the capital stock employed in production and rates of return are being equalised across regions.

–modelled with a labour-leisure decision as in Bekkers et al. (2017b)– raises the welfare effects, although it is clear from the figure that the effect of endogenous capital accumulation is larger. Table 3 shows that the welfare effect rises from 1.11% to 1.3% with endogenous labour supply. Combining endogenous labour supply with endogenous capital raises the welfare effects even more.

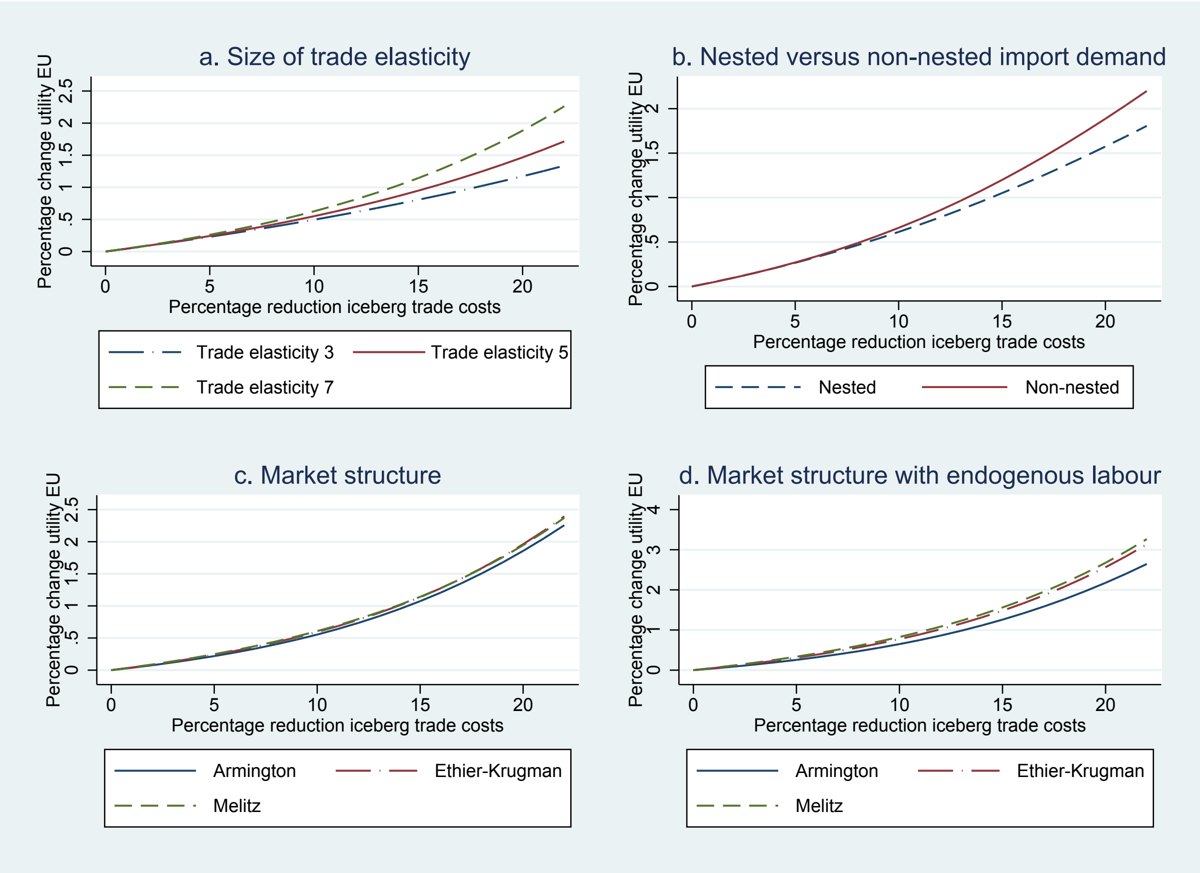

Figure 3: Impact of different modelling features on the welfare gains from trade cost reductions between TTIP partners

Source: Own calculations with flexible CGE-model as described in Hertel and Tsigas (1997), Hertel (2013a), and Bekkers et al. (2017b).

8. Size of trade elasticities. It has been common knowledge in the CGE literature that the welfare gains from trade cost reductions rise with the size of the trade elasticities (see for example, Harrison et al., 1997). With higher trade elasticities there is more scope for substitution towards countries reducing trade costs. For example, with higher trade elasticities a reduction in EU trade costs to import from the US leads to more substitution away from domestic varieties and from varieties exported by countries supplying low-quality goods.[24] Felbermayr et al. (2013a) and Felbermayr et al. (2015) find instead that the welfare effects of TTIP rise with a smaller trade elasticity for the TTIP partners.[25] This seemingly puzzling result can be explained by the fact that these authors also adjust their calculation of the trade cost reduction as a result of introducing TTIP when changing

[24] A recent finding in the quantitative trade literature –which focuses on the welfare gains from trade as measured by the import share– shows that the welfare gains are smaller the larger the trade elasticity is (Arkolakis et al., 2012). However, note that this result is about the welfare gains from trade, and not –as in this study– about the welfare gains from reductions in trade costs.

[25] See respectively Table A.II.5 and Table 11 of the two studies. In Felbermayr et al. (2015) it is only shown that the variance of the welfare effects becomes larger for a smaller trade elasticity (moving it from 7 to 5), but this obviously reflects larger gains for the TTIP partners and larger losses for countries not in TTIP.

the trade elasticity. The percentage trade cost reduction is calculated from $\exp\left(-\frac{\delta}{\theta}\right)-1$ with δ the coefficient on the FTA dummy and θ the trade elasticity. So a smaller trade elasticity corresponds henceforth with a larger trade cost shock.

Figure 3 (panel a) confirms the common knowledge in the CGE literature: the welfare gains are considerably larger when the trade elasticity rises. For uniform trade elasticities of 3, 5 and 7 the welfare gains in the EU of a 13% reduction in iceberg trade costs are respectively 0.67%, 0.77% and 0.91%.

9. Nested import demand. With nested import demand, consumers first chose between domestic and (aggregate) imports and after that, between imports from different countries. The elasticity of substitution between domestic and imported goods is usually set smaller than between imports from different sources. In the GTAP and MIRAGE models they are typically 50% smaller. Fontagné et al. (2013), using the MIRAGE model, work with nested preferences, whereas the studies by Francois et al. (2013) and Egger et al. (2015a) assume non-nested preferences. Figure 3 (panel b) shows that welfare effects are considerably smaller with nested preferences, when setting the parameters such that elasticities between imports and domestic goods are 50% smaller than between imports from different sourcing countries.

10. Market structure. The benchmark model used in CGE models is the Armington model featuring CES preferences across varieties from different countries of origin (Hertel and Tsigas, 1997). The SG literature often works with an Eaton-Kortum setup based on stochastic Ricardian technology differences between countries. For instance, Aichele et al. (2014a) choose an Eaton-Kortum setup based on Caliendo and Parro (2015). Some CGE models work with monopolistic competition featuring love for variety, either with homogeneous firms (Ethier-Krugman) or with heterogeneous firms (Melitz). Arkolakis et al. (2012) show that the welfare gains from trade are identical in the different setups in a single-sector model. In a multiple sector setting the monopolistic competition model contains an additional effect through the reallocation of inputs across sectors. More inputs in a sector raise welfare as a result of the love of variety property of the model –since more varieties can be produced. However, with fixed endowments, an increase in resources in one sector requires a reduction in resources in another sector. As a result the variety effects will cancel out, depending on the importance of love of variety (determined by the substitution elasticity) in the different sectors.[26]

    Figure 3 (panel c) displays the welfare changes for the Armington model, the Ethier-Krugman model and the Melitz model. Although the Melitz model is not used in any of the TTIP studies, we report results with this model for completeness.[27] The figure shows that the additional welfare gains when moving to monopolistic competition are limited, providing support for the argument in Arkolakis et al. (2012) that additional resources and thus varieties in some sectors go along with reduced resources in other sectors. Figure 3 (panel d) shows, moreover, that the additional welfare gains rise substantially when including endogenous labour supply.[28] Table 3 shows that the welfare effects rise by

[26] Balistreri et al. (2010a) argue that the welfare gains from trade liberalisation are much larger in a Melitz setting than an Armington-economy, which seems to be at odds with the findings in Arkolakis et al. (2012). The reason for the much larger results is that Balistreri et al. (2010a) introduce endogenous labour supply. As a result the labour supply-enhancing effect of trade liberalisation has a much stronger effect in the Melitz model with love of variety than in the Armington model. The general implication is that welfare effects are larger under monopolistic competition than Armington if factor supply is endogenous or if production factors are drawn into sectors with a strong love of variety.

[27] Further discussion of the Melitz model and a description of its modelling in a CGE setting can be found in Bekkers and Francois (2015).

[28] The difference between Armington on the one hand and Ethier-Krugman and Melitz on the other hand falls far short of the differences in Balistreri et al. (2010a). This can be explained by the fact that in Balistreri et al.

about 5% without endogenous labour supply when moving from Armington to Ethier-Krugman and Melitz, whereas the welfare effects rise by about 20% with endogenous labour supply. In the second part of the report (Sections 6 to 8) we will discuss the effects of firm heterogeneity into more detail.

4.2 Economic models in the different studies

In this section we describe the model characteristics of each of the TTIP studies. This will provide the information needed to later compare the different modelling features and explain the diverging welfare results.

4.2.1 CEPR Study (Francois et al., 2013)

The CEPR study uses a variant of the GTAP CGE-model.[29] A representative household demands both public and private goods with non-homothetic preferences across private goods from different sectors reflecting non-constant budget shares across sectors. Gross output is produced employing multiple (partially immobile) production factors and intermediate inputs in production, thus implying intermediate production linkages. Preferences are characterised by love of variety across varieties produced by identical monopolistically competitive firms. Profit margins are varying to enable the modelling of NTMs as generating economic rents besides economic costs.[30] Capital is one of the production factors. Savings and investment are endogenous with a so-called global bank allocating savings to investment across regions. In deviation from the GTAP model changes in investments affect the capital stock reflecting the long-term focus of the study (Francois et al., 1996). The model features import tariffs, export subsidies, income and value-added taxes and a transport sector for the shipping of internationally traded goods. Finally the labour market is characterised by a long-run approach where sources of employment and unemployment are "structural" (rather than cyclical). This means that unemployment is fixed in the long run and as such, it does not imply full-employment.[31] The long-term fixed labour supply is combined with flexible market-clearing wages. In this sense, changes in labour demand are captured through wage changes.

4.2.2 CEPII study (Fontagné et al., 2013)

The CEPII study uses the CEPII in-house CGE model: MIRAGE. This model is a CGE model similar to GTAP and as such, it shares the main characteristics with the CEPR model described in the previous subsection.[32] There are some notable differences. First, MIRAGE is a multi-period model with recursive dynamics. The endogenous capital stock is a function of investment in earlier periods. Monopolistic competition is implemented differently with a nested preference structure. Both differences are discussed into more detail in Section 5 on the comparison of modelling outcomes.

4.2.3 Egger et al. (2015a)

The study by Egger et al. (2015a) uses the same model as the CEPR-study, so the reader is referred to Subsection 4.2.1.

(2010a) the labour supply elasticity is not disciplined by estimates in the empirical literature like in Bekkers et al. (2017b).

[29] The main characteristics and references to the standard GTAP model are detailed in Hertel and Tsigas (1997) and Hertel (2013a).

[30] Positive profits are combined with free entry employing the so-called small group assumption generating endogenous markups in the monopolistic competition model (Francois et al., 2012).

[31] It is a common mistake to take CGE models to be full-employment models. For instance, this is wrongly stated in Capaldo (2014) and Rodrik (2015).

[32] For more details on the MIRAGE model see Bchir et al. (2002).

4.2.4 Felbermayr et al. (2015)

The economic model in Felbermayr et al. (2015) is based on Egger and Larch (2011) who develop a single-sector monopolistic competition model. Preferences are based on love-of-variety and identical monopolistically competitive firms can sell goods to multiple destinations. The novel feature of the model is that it can account for zero trade flows as a result of export-specific fixed costs. Only firms that sell enough to earn back the export-specific fixed costs will export to that market. More favourable market conditions or lower fixed costs imply that all firms can start exporting in the model, in contrast to a firm heterogeneity model with an extensive margin (Helpman et al., 2008), where only a subset of firms starts to export. As a result the extensive margin effect is potentially large. However, the extensive margin (or selection) effect is disciplined by the empirically estimated effect of TTIP on the extensive margin. The authors calculate the welfare effects of changes in trade costs by solving simultaneously for the new levels of GDP and of the multilateral resistance terms. Baseline trade costs are calibrated to fitted trade costs.

4.2.5 Felbermayr et al. (2013)

The model to explore the welfare and trade effects is the same structural gravity model as in Felbermayr et al. (2015).[33] Henceforth a single-sector Krugman model is used with welfare effects calculated by solving simultaneously for new GDP levels and multilateral resistance terms.

This study also examines the labour market effects of TTIP. To do so the authors follow Heid and Larch (2013) who extend the Arkolakis et al. (2012) approach with endogenous employment. Henceforth the study does not take into account firm heterogeneity. In the companion study for the German science ministry (Felbermayr et al., 2013a), labour market effects are explored within the framework of the firm heterogeneity model of Felbermayr et al. (2011), limited to a setting with 5 regions. Contrary to what appears to be the case, the simulations with the labour market model are separate from the simulations with the main model determining welfare effects. Since our main focus is a comparison of the welfare effects in the different studies and the core simulations do not incorporate the labour market modelling, we do not discuss this part any further here.

4.2.6 Aichele et al. (2014a)

In contrast to other SG applications on TTIP, Aichele et al. (2014a) use a multi-sector framework with intermediate linkages based on the stochastic Ricardian model by Eaton and Kortum (2002). The model contains Cobb-Douglas preferences of consumers across 32 sectors. Each sector produces final goods employing a combination of labour and intermediate inputs. Intermediate inputs can be sourced from all trading partners. As in Eaton and Kortum (2002) intermediates are sourced from the cheapest trading partner giving rise to a gravity-type expression for the share of intermediates sourced from each of the trading partners as a function of bilateral trade costs, income and multilateral resistance terms. This expression is used both in the simulations and serves as a basis for the empirical gravity equation to estimate the trade elasticities and the impact of TTIP. Following Caliendo and Parro (2015) the model contains tariff revenues but no other taxes, only one factor of production (one labour-type and thus, no capital). Consumers do not directly import goods from other countries, but buy sector composites of intermediates. Only intermediates are traded internationally.

The change in trade costs as a result of the TTIP-experiment is simulated employing exact hat-algebra as introduced by Dekle et al. (2008) working with a model with 134 regions. The

[33] This becomes clear after consulting the study referred to which contains more details on the employed approach (Felbermayr et al., 2013a).

import- and industry- and cost-shares required to simulate the model are taken from the GTAP database. The authors employ as import-shares the average import-shares across different users (consumers, government, firms and investors). The only structural parameters required are the trade elasticities being equal to the Frechet productivity dispersion parameters in the Eaton-Kortum model. To obtain these elasticities the authors estimate a gravity equation identifying the trade elasticity employing the estimated tariff elasticity. The trade data are taken from UN COMTRADE which are also the basis for the GTAP trade data. No other structural parameters are required since sectoral demand shares and the share of intermediates and value added are all assumed to be Cobb-Douglas.

4.2.7 Carrere et al. (2015)

Carrere et al. (2015) build a multi-sector model of trade and unemployment by combining Diamond-Mortensen-Pissarides search-and-matching frictions with an Eaton-Kortum trade framework. Search frictions are determined by the matching productivity and the cost of posting vacancies, which in turn determine the level of unemployment: higher search frictions lead to higher equilibrium unemployment. Crucial in the model is that it is assumed that search frictions are sector-specific. Workers decide irreversibly in which sector they want to work by an arbitrage condition imposing that the expected wage (wage times the probability of being employed) is identical in all sectors. This reflects risk-neutrality among agents. As a result wages are higher in sectors with higher equilibrium unemployment to compensate workers for the higher probability of getting unemployed.

Sector-specific search frictions are calibrated and estimated from data on sectoral unemployment taken from the ILO's key indicators of the labour market (KILM) database.[34] Given the baseline calibration the authors then simulate the effects of a trade cost shock as a result of TTIP. This shock changes the real wage and the allocation of workers across sectors and as a result also the aggregate unemployment rate. If the trade shock reallocates workers from sectors with higher frictions to sectors with lower frictions, then this is translated into a decrease in unemployment, as the labour demand from the expanding sectors coupled with their lower labour frictions will be translated into a higher than average hiring of workers.

5 Comparison of studies

The predicted economic effects of TTIP in the different studies vary considerably. As Table 1 shows, the economic effects vary widely from 0.3% real income increase in both the EU and the US in the study by Fontagné et al. (2013) to more than 10% welfare increase for the US in Felbermayr et al. (2013). In this section we describe how these differences can be explained based on intrinsic differences in the employed models.[35]

5.1 Differences in simulation models

To make a transparent comparison between the different studies we associate the differences in NTM trade cost reductions with the differences in welfare effects. Table 4 employs the average trade cost reductions and the expected welfare effects reported in Table 1. Next we take a benchmark study to which all the other studies are compared. As benchmark study we use Egger et al. (2015a), since this study seems to be in the middle, both in terms of estimated

[34] As an alternative, the paper also employs a version of the model with occupation-specific labour market frictions. This in turn implies different frictions at the sector level given that certain occupations occur more frequently in certain sectors. However, when estimating the parameters of the model, the authors return to the baseline model and estimate sector-specific search frictions.

[35] The study by Capaldo (2014) on TTIP suffers from a series of methodological flaws. For space reasons we delegated a discussion of this study to Appendix B.

trade cost reductions and in terms of welfare effects. We then calculate how much larger (or smaller) both the average trade cost reduction and the average welfare effect are in comparison to the benchmark study. If the difference in welfare effects is larger than the difference in trade cost reductions, this would mean that the study generates larger welfare effects based on the same level of trade cost reductions. The size of the difference in trade cost reductions cannot be translated one-to-one into the size of the difference in welfare effects, since differences in trade cost reductions do not map proportionally into differences in welfare effects. In other words, the welfare effect of doubling the trade cost shocks from 5% to 10% is smaller than the welfare effect of doubling the trade cost shock from 10% to 20%. The relation between trade cost changes and percentage welfare effects becomes especially non-linear for larger trade elasticities.[36]

Table 4: Comparison of reductions in iceberg trade costs τ and welfare effects in different studies

	Reduction tau			Welfare effects			Trade elasticity	Relative to Egger et al., 2015	
	EU	USA	Average	EU	USA	Average		Change tau	Welfare effect
CEPR study	-2.3	-2.8	-2.5	0.5	0.4	0.5	5.1	19.4%	25.6%
CEPII study	-6.5	-7.7	-7.1	0.3	0.3	0.3	4.0	54.5%	16.6%
Egger et al., 2015	-12.4	-13.6	-13.0	2.3	1.0	1.8	5.1	100.0%	100.0%
Carrere et al., 2015	-15.1	-15.1	-15.1	0.2	0.3	0.2	3.2	116.2%	11.3%
Felbermayr et al., 2015	-15.9	-15.9	-15.9	3.9	4.9	4.3	7.0	121.9%	237.1%
Felbermayr et al., 2013	-16.2	-16.2	-16.2	8.0	13.4	10.1	8.0	124.6%	556.9%
Aichele et al., 2014	-12.7	-13.8	-13.2	2.1	2.7	2.3	6.8	101.6%	129.0%

Source: Own calculations based on reported results from cited studies. Notes: Reported trade elasticities are the trade-weighted average trade elasticities from each study.

Table 4 also reports the trade-weighted averages of the sectoral trade elasticities in the different studies, since these differences play an important role in explaining differences in welfare effects. To interpret the results in Table 4 we compare in turn Aichele et al. (2014a), Fontagné et al. (2013), Felbermayr et al. (2013) and Felbermayr et al. (2015) and Carrere et al. (2015) with Egger et al. (2015a). We do not include a detailed comparison with Francois et al. (2013), as the results are very similar to Egger et al. (2015a), i.e. for identical trade cost reductions, welfare effects are similar. This is as expected, since the studies employ the same economic model. The larger relative welfare effects in Francois et al. (2013) compared to the relative trade cost effects (about 25% larger: 20% relative to 25%) can be explained from the fact that in Francois et al. (2013) spillovers effects are part of the baseline scenario, whereas in Egger et al. (2015a) they are not.

5.1.1 Comparison with Aichele et al. (2014a)

First, we compare Egger et al. (2015a) with Aichele et al. (2014a). The trade cost reductions are almost identical, whereas the welfare effects are 128% larger in Aichele et al. (2014a). Hence, the Aichele et al. (2014a) model generates larger welfare effects for the same trade cost reductions, although the difference is not large. To explain this difference we use the analysis in Section 4 on differences in the methodology of TTIP studies. Of the nine features discussed in Subsection 4.1 five features are different and could thus potentially explain the differences: multiple factors, non-homothetic preferences and Cobb-Douglas nests, market structure, the treatment of capital and the size of trade elasticities.[37] Aichele et al. (2014a) assume a single production factor (labour) whereas Egger et al. (2015a) contains multiple factors of production, but the analysis in Subsection 4.1 shows that the differences in welfare effects are very small

[36]These findings are based on calculations of the impact of reductions in iceberg trade costs between the EU and the US in multi-sector Armington and Ethier-Krugman models calibrated to GTAP-9 data (16 sectors, 17 countries, 2 factors). Results are available upon request.

[37]The other features cannot explain the differences: since the studies do not differ with respect to these features: intermediate linkages; multiple sectors; endogenous labour; and nested preferences.

between single and multiple production factors. Second, non-homothetic preferences also do not make a big difference, but Cobb-Douglas preferences do. Aichele et al. (2014a) work with a Cobb-Douglas nest between intermediates and value added, whereas Egger et al. (2015a) impose Leontief nests, which reduce the welfare gains. Hence, this feature can explain part of the larger welfare effects in Aichele et al. (2014a). Third, Egger et al. (2015a) features (small group) monopolistic competition, whereas Aichele et al. (2014a) work with perfect competition, but this feature does not have a huge impact on the welfare effects. Fourth, the endogeneity of capital in Egger et al. (2015a) raises the welfare effects significantly. Fifth, Aichele et al. (2014a) work with a considerably larger average trade elasticity (6.79 versus 5.11) and this makes the welfare effects considerably larger.

To summarise, two features of the model in Aichele et al. (2014a), a Cobb-Douglas nest between intermediates and value added and a larger average trade elasticity, both lead to larger welfare effects and are thus in line with the larger predicted welfare effects in this study. One feature, endogenous capital, raises the welfare effects in Egger et al. (2015a) and is thus at odds with the predicted welfare effects. We conclude that the first two features must have a bigger impact than the third one.

5.1.2 Comparison with Fontagné et al. (2013)

Second, we compare Egger et al. (2015a) with Fontagné et al. (2013). Table 4 makes clear that the difference in trade cost reductions is much smaller than the difference in welfare effects. Explaining this difference based on differences in model scope seems hard: both sets of studies employ a CGE model with very similar features. Only three features are different. First, the average trade elasticity in Fontagné et al. (2013) is smaller and thus drives down the welfare effects in line with predicted effects. Second, capital is modelled in a different way in the two studies. In Egger et al. (2015a) capital is mobile and shifts between regions until the rate of return is equalised. Moreover, in deviation from the baseline GTAP model, additional capital in a certain region relative to the baseline becomes online, i.e. can be employed in production. As pointed out in the documentation on the MIRAGE model in Bchir et al. (2002), in Fontagné et al. (2013) capital cannot move freely between regions nor between sectors. In particular installed capital is immobile. Since the model is dynamic though, the capital stock does adjust over time as a function of investment and since investment flows responds to differences in rates of return, capital accumulation works fairly similar in Egger et al. (2015a) and Fontagné et al. (2013). The difference in modelling capital can henceforth not explain the difference in predicted economic effect of the two models.

Third, although both studies work with monopolistic competition for services (except transport) and manufactures, the implementation is different. Fontagné et al. (2013) has a nested structure for demand with four nests.[38] Goods can be of two different quality levels and the first nest constitutes the choice between high and low quality goods, supplied respectively by high and low income countries. In the second nest consumers have to choose between domestic and imported varieties. This nest only exists for the quality level also produced at home. In the third nest consumers choose between varieties imported from different sources and finally in the fourth nest they choose within each of the sourcing countries between varieties supplied by different firms. The model is calibrated to the Armington elasticities between goods from different source countries, as provided by the GTAP-5 database and crucially the substitution elasticities for the other nests are not identical. In particular, the elasticities fall when moving up a nest and they rise when moving down one nest.[39] In comparison Egger et al. (2015a)

[38]Fontagné et al. (2013) work with small-group monopolistic competition with endogenous markups, whereas Francois et al. (2013) employ large-group monopolistic competition with fixed markups. However, this difference is not an important factor in the differences in outcomes.

[39]The formula is $\sigma_{dom,int} - 1 = \sqrt{2}\,(\sigma_{imp} - 1)$ for example for the relation between the Armington elasticity between varieties from different sources, σ_{imp}, and the substitution elasticity between domestic and imported

work with identical substitution elasticities at all nests, effectively not modelling any nests. The implication is that the welfare effects of reductions in trade costs are smaller in Fontagné et al. (2013) as a result of a different implementation of monopolistic competition for two reasons. First, the substitution elasticities between domestic and imported varieties and between varieties of different quality levels are much smaller in Fontagné et al. (2013), thus generating smaller welfare effects. Second, the substitution elasticities between varieties are larger in Fontagné et al. (2013), implying smaller love of variety forces and thus, less welfare gains from the increased availability of varieties.

5.1.3 Comparison with Felbermayr et al. (2013) and Felbermayr et al. (2015)

Third, we compare Egger et al. (2015a) with both Felbermayr et al. (2013) and Felbermayr et al. (2015). In the latter studies welfare effects are much larger than could be explained by the difference in trade cost reductions. Hence, differences in modelling features should explain the larger effects in these studies. Relevant differences in modelling features are the presence of intermediate linkages and endogenous capital, the size of trade elasticities and baseline calibration. The first two modelling features should make the welfare effects in Felbermayr et al. (2013) and Felbermayr et al. (2015) smaller: there are no intermediate linkages in Felbermayr et al. (2013) and Felbermayr et al. (2015) and capital is exogenous.[40] However, the larger trade elasticities cannot explain the much larger welfare effects. This becomes clear by comparing the study with Aichele et al. (2014a). Trade cost shocks and trade elasticities are similar, whereas welfare effects are much larger in Felbermayr et al. (2013) and Felbermayr et al. (2015). Therefore, the differences in welfare results must come from the difference in baseline calibration.

In both studies the welfare effect is calculated by comparing GDP before and after a reduction in iceberg trade costs, taking into account general equilibrium changes in multilateral resistance terms. The baseline trade costs (before the reduction) are based on the fitted values of observable trade costs from a gravity equation employing only international trade data and calibrating domestic shares based on the estimated gravity equation. As such unobservable trade costs are neglected, generating huge differences between actual import shares and baseline import shares. In particular, the calibration generates relatively large international import shares. In other words, in the baseline countries trade much more than they actually do. In Subsection 4.1 we have shown that this calibration leads to very large welfare effects compared to a calibration to actual import shares. Felbermayr et al. (2013) and Felbermayr et al. (2015) do not explicitly describe whether domestic trade flows are neglected and how trade costs for domestic flows are calibrated. However, our simulation results indicate that they must have used fitted domestic trade costs based on a gravity estimation without intra-national flows, since this calibration generates welfare effects close to the ones found in Felbermayr et al. (2015).

In Felbermayr et al. (2013) welfare effects are even larger than in Felbermayr et al. (2015). Whereas the methodologies are identical, there are three differences between the two studies: the sample of countries is smaller (126 versus 173), the included gravity regressors are different and the size of the extensive margin effect could be different. Bekkers et al. (2017a) shows that the impact of a changing sample is negligible on the welfare effects. Using other gravity regressors could change the effects by up to 20%, which cannot explain that Felbermayr et al. (2013) get welfare gains for TTIP-partners more than 100% larger than in Felbermayr et al. (2015). So the size of the extensive margin effect is the only factor that remains to explain the differences in outcomes. Both studies employ the same model, which allows for zero trade flows. Changes in trade costs can change the pairs of countries that display positive trade. Felbermayr et al. (2015) report the effects both with and without the extensive margin effect, showing that the impact of the extensive margin is negligible. On the other hand, Felbermayr et al. (2013)

varieties, $\sigma_{dom,imp}$. Moving further up or down the nest structure the relation between elasticities is identical.

[40] Other features that are different, number of sectors, number of factors, non-homothetic preferences, do not have a big impact on welfare effects.

only report total effects. Therefore it is not clear what the role of the extensive margin effect is in Felbermayr et al. (2013), but it is the only credible explanation for the differences in welfare effects. However, a large extensive margin effect on welfare is problematic. In the theoretical model firms are identical. This means that all firms enter a market with identical sales when a country starts to export to a certain market. As a result the extensive margin effect is huge. In reality the effect of switching from zero to positive trade should be moderate. If trade costs fall such that positive trade is possible, only some firms will enter the market with a small amount of export sales, which consequently can only have a small welfare effect.[41]

5.1.4 Comparison with Carrere et al. (2015)

We first compare the real wage effects in Carrere et al. (2015) with those in Egger et al. (2015a). The unemployment effects in Carrere et al. (2015) are discussed separately, since the latter study does not model unemployment explicitly. The real wage effects relative to Egger et al. (2015a) are small in comparison to the relative trade cost reductions. Three factors can explain this. First, the model in Carrere et al. (2015) has perfect competition and thus does not feature scale or love-of-variety effects. Second, the trade elasticity of 3.2 is much smaller than the average trade elasticity of 5.1 in Egger et al. (2015a), thus generating smaller effects.[42] Third, Egger et al. (2015a) features endogenous capital, raising the welfare effects. An additional factor that can explain the smaller welfare effects in Carrere et al. (2015) is that the positive effect of lower trade costs through TTIP is partially absorbed by lower unemployment (and more employment), whereas in Egger et al. (2015a) and the other studies labour supply is exogenous and all the adjustment takes place through real wages.[43]

5.2 Synthesis NTM-effects TTIP-studies

The analysis in the previous subsections enables us to classify the different studies based on differences in expected trade cost reductions and in the employed economic model and draw conclusions on the expected economic effects. Table 5 gives a stylised representation of the studies in terms of expected iceberg trade cost reductions τ and the size of the economic effects generated by the economic model. The table has two axes, where each one has a different range of results (small, medium and large).[44] For example, Francois et al. (2013) is classified in the entry with small estimated trade cost reductions and relatively small welfare effects calculated with their economic model.

As argued in Subsection 5.1.3 we consider the economic effects generated by the studies by Felbermayr et al. (2013) and Felbermayr et al. (2015) as too large, because of the way the baseline is calibrated. Choosing between the other economic models is difficult. The medium economic effects in Aichele et al. (2014a) are generated with a perfect competition model without endogenous capital. The CGE models employed by CEPII and CEPR are both models with endogenous capital accumulation and imperfect competition and still generate relatively large differences in welfare effects for the same reduction in trade costs, depending in particular on the inclusion of nested preferences and the size of substitution elasticities. Therefore, based on the uncertainty regarding both the size of the trade cost reductions and the trade elasticities

[41] The extensive margin at the country- or sector-level should be distinguished from the firm-level extensive margin. A large part of the effect of changes in trade costs could be due to a changing number of firms exporting (firm-level extensive margin) as in Chaney (2008).

[42] Other differences from Subsection 4.1, multiple factors of production, non-homothetic preferences and endogeneity of capital, do not generate large differences in welfare effects.

[43] Negative broader welfare effects in Carrere et al. (2015) in the US and a couple of European countries, raises three points of concern. In particular, the negative overall welfare effects in some countries like Ireland and the US are driven by the fact that changes in real income and unemployment get equal weight in determining welfare, based on the assumption that unemployed workers receive zero income.

[44] To keep the table concise we abstract from differences in trade elasticities.

Table 5: Classification of studies

Reductions τ:	Economic Model: Small Effects: <0.5%	Medium Effects: 1%-2.5%	Large Effects: >4%
Small: < 5%	CEPR study		
Medium: 5%-15%	CEPII study	Egger et al. 2015 Aichele et al. 2014	
Large: >15%			Felbermayr et al. 2013, 2015

Source: Own calculations based on reported results from cited studies.

and the choice of model (perfect/imperfect competition and exogenous/endogenous capital) we conclude that reasonable real income effects from TTIP range between 0.2% and 2%.

6 Firm heterogeneity model

We incorporate firm heterogeneity into the standard static CGE-model GTAP. To model the Armington, Ethier-Krugman, and Melitz model in one structure we add three components to the equations for international trade in the GTAP model: a demand shifter, a supply shifter, and a trade cost shifter (also called generalized iceberg trade costs). Depending on the specification of these three components, we can nest the three models within a single structure.

6.1 Modifying international trade

In the standard GTAP there are four types of agents (or end users) in country s : private households with superscript pr, government with superscript go, investors with superscript in, and firms from sector j with superscript fi_j. We assume the reader is familiar with the structure of the GTAP model.[45] Each of the agents divide their demand in sector i, q_{is}^{ag}, into domestic demand, $q_{is}^{d,ag}$, and import demand, $q_{is}^{m,ag}$, according to a CES utility function with substitution elasticity ρ:

$$q_{is}^{ag} = \left(\left(q_{is}^{d,ag} \right)^{\frac{\rho_i - 1}{\rho_i}} + \left(q_{is}^{m,ag} \right)^{\frac{\rho_i - 1}{\rho_i}} \right)^{\frac{\rho_i}{\rho_i - 1}} \tag{2}$$

Total import demand, q_{is}^m, consists of the sum over the four groups of agents, $q_{is}^m = \sum_{ag} q_{is}^{m,ag}$, and is in turn allocated across demand from the different sourcing countries, q_{irs}, according to a CES utility function, featuring a demand-shifter, e_s^m:

$$q_{is}^m = e_{is}^m \left(\sum_{r=1}^{S} \left(q_{irs} \right)^{\frac{\sigma_i - 1}{\sigma_i}} \right)^{\frac{\sigma_i}{\sigma_i - 1}} \tag{3}$$

The demand shifter e_{is}^m will differ from 1 in the Melitz model. Import demand can be written as follows:

$$q_{irs} = \left(e_{is}^m \right)^{\sigma_i - 1} \left(\frac{p_{irs}}{p_{is}^m} \right)^{-\sigma_i} q_{is}^m = \left(e_{is}^m \right)^{\sigma_i - 1} \left(\frac{\frac{t_{irs} ta_{irs} p_{irs}^{cif}}{c_{ir}^m}}{p_{is}^m} \right)^{-\sigma_i} q_{is}^m \tag{4}$$

[45] We refer to for example Hertel (2013b) and Bekkers et al. (2017a) for a description of the general structure of the GTAP-model. We describe here only the parts of the model that are changed by extending the model with monopolistic competition and firm heterogeneity.

t_{irs} are the (generalized) iceberg trade costs, c_{ir}^m is a supply shifter, p_{irs}^{cif} is the cif-price, exclusive of the iceberg trade costs, and ta_{irs} are the bilateral tariffs. p_{is}^m is the price index of total import demand, q_{is}^{im}, and defined as:

$$p_{is}^m = \left(\sum_{r=1}^{S} \left(\frac{t_{irs} ta_{irs} p_{irs}^{cif}}{c_{ir}^m e_{is}^m} \right)^{1-\sigma_i} \right)^{\frac{1}{1-\sigma_i}} \tag{5}$$

$q_{is}^{d,ag}$ also features a demand shifter and domestic demand, $q_{iss}^{d,ag}$, is given by $q_{is}^{d,ag} = e_{is}^d q_{iss}^{d,ag}$. We can thus express $q_{iss}^{d,ag}$ as follows:

$$q_{iss}^{d,ag} = \left(e_{is}^d\right)^{\rho-1} \left(\frac{p_{iss}^{d,ag}}{p_{is}^{ag}} \right)^{-\rho_i} q_{is}^{ag} = \left(e_s^d\right)^{\rho_i-1} \left(\frac{\frac{ta_{is}^{d,ag} tp_{is} p_{is}^{ib}}{c_{is}^d}}{p_{is}^{ag}} \right)^{-\rho_i} q_{is}^{ag} \tag{6}$$

p_{is}^{ib} is the domestic production price or the price of input bundles, c_{is}^d is the domestic supply shifter, $ta_{is}^{d,ag}$ and tp_{is} are respectively the group specific import tariffs and the production taxes, and p_{is}^{ag} is the price index corresponding with aggregate sectoral demand of group ag, q_{is}^{ag}, and defined as:

$$p_{is}^{ag} = \left(\left(\frac{ta_{is}^{d,ag} tp_{is} p_{is}^{ib}}{e_{is}^d c_{is}^d} \right)^{1-\rho_i} + \left(ta_{is}^{m,ag} p_{is}^m\right)^{1-\rho_i} \right)^{\frac{1}{1-\rho_i}} \tag{7}$$

Since the demand and supply shifters are already part of p_{is}^m they only appear in the domestic price part.

6.2 Modelling Armington, Ethier-Krugman, and Melitz

This subsection presents the three trade structures and the theoretical expressions for the demand, supply, and trade cost shifters. The implementation in the code is presented in the next subsections. Formal derivations of expressions for the different shifters can be found in Appendix C.

6.2.1 Armington

The Armington model is the default trade structure in the standard GTAP model. Goods are differentiated by country of origin and all goods produced by the same country are homogeneous. This means that all goods from country r imported by country s have the same price as modelled in the previous subsection with the demand and supply shifters, e_{is} and c_{ir}, equal to one (and the corresponding variables in the code in relative changes equal to zero). The trade cost shifter, t_{irs}, is equal to plain iceberg trade costs, τ_{irs}. To model iceberg trade costs explicitly in the code, we include the variable *itc(i,r,s)* with *ams(i,r,s)=-itc(i,r,s)* in the Armington world.

6.3 Ethier-Krugman

The Ethier-Krugman model combines love-of-variety in consumption, increasing returns in production, and monopolistic competition as market structure. Utility of agent ag in country s is a CES aggregate over the different varieties $\omega \in \Omega_{irs}$ produced in r and consumed in s. The dual price index can be written as an aggregate over the price of the varieties, $p^o(\omega)$:

$$p_{is}^{ag} = \left(\left[\left(M_{is}^{\nu_i-1} \sum_{r=1}^{S} \int_{\omega\in\Omega_{irs}} p^{ag,o}(\omega)^{1-\sigma_i} d\omega \right)^{\frac{1-\rho_i}{1-\sigma_i}} + \left(M_{is}^{\nu_i-1} \int_{\omega\in\Omega_{is}^d} p^{ag,o}(\omega)^{1-\sigma_i} d\omega \right)^{\frac{1-\rho_i}{1-\sigma_i}} \right] \right)^{\frac{1}{1-\rho_i}} \tag{8}$$

p_{is}^{ag} could be price index of private household and government consumption or of intermediate input demand of one of the sectors, both featuring love-of-variety. Krugman (1980) focused on trade in final goods, whereas Ethier (1982) emphasized trade in intermediates. Since the GTAP model features both final goods and intermediates, we talk about the Ethier-Krugman model.

To separate the strength of love of variety from the substitution elasticity, we include the term in M_{is} in the utility function as in Benassy (1996). With $\nu_i = 1$ the utility function collapses to the standard CES and a smaller ν_i weakens the strength of love-of-variety. Further discussion is provided in Bekkers and Francois (2018).

Firms produce under increasing returns to scale with identical fixed cost a_{ir} and marginal costs b_{ir}. Combining increasing returns to scale in production with love-of-variety preferences implies that an increase in the number of input bundles used in production leads to a more than proportional increase in utility, since more varieties can be produced. Phrased differently marginal costs at the aggregate level (for the entire sector) fall in the number of input bundles. This can be modelled by a supply shifter c_{ir}^{so} (with $so = d, m$) falling in the number of input bundles. Combining markup pricing, free entry, and factor market equilibrium generates the following expression for c_{ir} (with $\gamma_{ek,i}$ a function of σ_i):

$$c_{ir}^{so} = \gamma_{ek,i} \left(\frac{\widetilde{q_{ir}^{ib}}}{a_{ir}} \right)^{\frac{1}{\sigma_i - 1}} \tag{9}$$

$\widetilde{q_{ir}^{ib}}$ is nearly proportional to the number of input bundles, q_{ir}^{ib}. Due to the presence of a transport sector we cannot write the number of varieties from country r, N_{ir}, exactly as a function of the number input bundles, q_{ir}^{ib}, and we have to subtract a term which is a function of the amount of transport services paid:

$$\widetilde{q_{ir}^{ib}} = q_{ir}^{ib} - \frac{\sigma_i - 1}{\sigma_i} \left(\sum_{s=1}^{S} \frac{N_{ir}\overline{r}_{irs}}{tp_{ir}p_{ir}^{ib}ta_{irs}\left(te_{irs} + \frac{p_{irs}^{ts}}{tp_{ir}p_{ir}^{ib}a_{irs}^{ts}} \right)} - \frac{N_{ir}\overline{r}_{irs}}{tp_{ir}p_{ir}^{ib}ta_{irs}} \right) \tag{10}$$

$\overline{r}_{irs}$ are the per-firm revenues net of the group-specific import tariffs. As discussed below, inclusion of the additional term on the RHS of equation (10) has only a marginal effect on the simulation results.

To capture the additional love-of-variety term, M_{is}, the demand-shifter e_{is}^{so} is written as a function of the number of input bundles from all trading partners:

$$e_{is}^{so} = \left(\sum_{r=1}^{S} \frac{\widetilde{q_{ir}^{ib}}}{a_{ir}} \right)^{\frac{\nu_i - 1}{\sigma_i - 1}} \tag{11}$$

Since fixed costs are not destination-specific, varieties are shipped to all trading partners. Therefore, the number of varieties in the Ethier-Krugman model does not vary by destination country and the expression on the RHS in equation (11) does not vary by country. Therefore, this term could also have been included in the supply-shifter. Putting this term in the demand-shifter makes it easier to switch between the Ethier-Krugman and the Melitz model, as in the Melitz model the additional love-of-variety term varies by country as a result of destination-specific fixed trade costs. The absence of destination-specific fixed costs also implies that the trade cost shifter, t_{irs}, is equal to iceberg trade costs, τ_{irs}.

6.4 Melitz

Demand under Melitz is like under Ethier-Krugman described by equation (8) with love-of-variety between varieties produced by different firms. The cost function is also identical, except for the fact that marginal costs, or its inverse productivity, φ, is heterogeneous across firms. Firms get to know their productivity upon paying sunk entry costs, en_{ir}, by drawing from a known distribution $G_{ir}(\varphi)$. We work with a Pareto distribution with shaper parameter θ_i and size parameter κ_{ir}:

$$G_{ir}(\varphi) = 1 - \frac{\kappa_{ir}^{\theta_i}}{\varphi^{\theta_i}} \tag{12}$$

Firms are subject to a fixed death probability δ and there is a steady state of entry and exit with the mass of entering and exiting firms identical. Firms producing in country r and selling in country s pay both icberg trade costs τ_{irs} and fixed export costs f_{irs}. For technical reasons we assume that the productivity level φ applies both to production and transportation costs, implying that more productive firms also require less transport services. Without this assumption the model would become intractable. Fixed costs are paid in input bundles of the exporting country. In our setting with multiple end users, importing country specific input bundles for fixed costs would lead to ambiguity as to which input bundles should be used and therefore we stick to the assumpion that fixed costs are paid in terms of exporting country bundles.

To determine the equilibrium price index we can impose an ex post zero cutoff profit condition (after firms know their productivity), an ex ante free entry condition (before drawing productivity), and factor market equilibrium. Like in the Ethier-Krugman model the combination of love-of-variety preferences with increasing returns to scale in production implies that marginal costs at the sectoral level fall with the number of input bundles, modelled by the supply shifter rising in the number of input bundles. However, sectoral marginal costs are now also affected by the price of input bundles. To make this clear we use the decomposition of changes in trade in Head and Mayer (2015) into an intensive margin, extensive margin, and compositional margin. An increase in the price of input bundles reduces trade along the intensive margin as in the Armington and Ethier-Krugman model, so is captured by the impact of p_{irs}^{cif} and p_{ir}^{ib} for respectively importer and domestic demand in equations (4) and (6). However, in the Melitz model there are two additional effects. Higher priced input bundles reduce the number of firms exporting, the extensive margin effect. As a result sectoral exports fall. This occurs because input bundles used in both marginal costs and fixed export costs are more expensive. But higher priced input bundles also imply that less productive firms cannot export anymore, the compositional margin effect. And as a result exports rise again. On net the extensive margin dominates the compositional margin. The extensive and compositional margin effects are captured by the impact of the price of input bundles on the supply shifter, as specified in the following equations (with $\gamma_{m,i}$ a function of σ_i and θ_i):

$$c_{ir}^{m} = \gamma_{m,i} \left(\frac{\kappa_{ir}^{\theta_i} \widetilde{q_{ir}^{ib}}}{\delta en_{ir}} \right)^{\frac{1}{\sigma_i - 1}} \left(tp_{ir} p_{ir}^{ib} \right)^{-\frac{\theta_i - \sigma_i + 1}{(\sigma_i - 1)^2}} \tag{13}$$

$$c_{is}^{d} = \gamma_{m,i} \left(\frac{\kappa_{is}^{\theta_i} \widetilde{q_{is}^{ib}}}{\delta en_{is}} \right)^{\frac{1}{\sigma_i - 1}} \left(tp_{is} p_{is}^{ib} \right)^{-\frac{\sigma_i(\theta_i - \sigma_i + 1)}{(\sigma_i - 1)^2}} \tag{14}$$

$\widetilde{q_{ir}^{ib}}$ is defined as in the Ethier-Krugman model in equation (10). The coefficient p_{ir}^{ib} differs for the domestic and import supply shifter. The reason is that the coefficient on p_{ir}^{ib} in the domestic supply shifter captures the impact on the extensive relative to the compositional margin through the price of bundles used in both marginal and fixed costs, whereas the coefficient on p_{ir}^{ib} in the import supply shifter only captures the impact through the price of bundles used in fixed costs. The impact through marginal costs of the extensive relative to the compositional margin adjustment will be captured in the trade cost shifter.

The trade cost shifter is also affected by the three margins of adjustment and is given by the following expression:

$$t_{irs} = \left(\left(p_{irs}^{cif}\right)^{\frac{\theta_i-\sigma_i+1}{\sigma_i-1}} \tau_{irs}^{\frac{\theta_i-\sigma_i+1}{\sigma_i-1}} ta_{irs}^{\frac{\theta_i-\sigma_i+1}{\sigma_i-1}+\frac{\theta_i-\sigma_i+1}{(\sigma_i-1)^2}} f_{irs}^{\frac{\theta_i-\sigma_i+1}{(\sigma_i-1)^2}} \right) \tau_{irs} \tag{15}$$

The last term outside of the brackets represents the impact of iceberg trade costs on the intensive margin, like in the other two models. In the Melitz model, iceberg trade costs also have an impact through the extensive and compositional margin, corresponding with the second term within brackets. For the same reason the cif-price, p_{irs}^{cif}, bilateral tariffs, ta_{is}, the fixed costs, f_{irs}, also appears between brackets. We see that larger iceberg and fixed trade costs raise generalized trade costs, t_{irs}, if $\theta_i > \sigma_i - 1$, corresponding with the extensive margin effect dominating the compositional margin effect, as will be discussed further in the subsection on trade margin decomposition.

The demand-side shifter in the Melitz model is also driven by the strength of the extensive margin relative to the compositional margin. In a market with a large effective market size (larger price indices p_{is}^{ag} and p_{is}^{so} and larger expenditures E_{is}^{ag}) more firms can profitably sell, so both the extensive margin and the compositional margin are larger. The demand shifter for source $so = d, m$ is thus defined as:

$$e_{is}^{so} = M_{is}^{\frac{\nu_i-1}{\sigma_i-1}} \left(\sum_{ag} M_{is}^{\nu_i-1} \left(\frac{p_{is}^{ag}}{ta_{is}^{so,ag} p_{is}^{so}} \right)^{\rho_i-1} \frac{\left(p_{is}^{so}\right)^{\sigma_i-1} E_{is}^{ag}}{ta_{is}^{so,ag}} \right)^{\frac{\theta_i-\sigma_i+1}{(\sigma_i-1)^2}} \tag{16}$$

M_{is} is equal to the sum of the number of varieties from all sourcing countries. There is only one demand-shifter for the different groups of agents ag. The reason is that exporter fixed costs are not agent specific. Upon paying the fixed costs to sell in destination market s, we assume that they are able to sell to all end users. So, the effective market size determining how many firms are able to sell in the market consists of the sum of demands by the different groups of agents.

6.5 New parameters in the model

We add the eight parameters in Table 6 to the parameter file, which are all sector-specific. These parameters are used to switch between the different models and parameterize the model, using empirically observable parameters. Some of the behavioral parameters employed in the code are functions of these parameters. We have decided to switch between models through changes in the parameter file instead of closure swaps in the command file. Although there are only a small number of additions to the core code, the trade and welfare decompositions imply quite a large number of equations that are model-dependent, thus implying quite a large number of swaps. Working with parameter values to switch between models is therefore easier.

Before introducing the parameters, we first observe that if the granularity parameter $\xi_i = \frac{\sigma_i-1}{\theta_i}$ would go to 1 the model would approach so-called full granularity with $\theta_i = \sigma_i - 1$. Under full granularity the Melitz model collapses to the Ethier-Krugman model. However, full granularity is a limiting case of the Melitz model, since average firm sales and other aggregates would not be defined anymore. In turn switching off variety scaling the two monopolistic competition models fall back to Armington. The first three parameters in Table 6 enable us to switch between the different models, and the last six parameters (from $GRAN$ to NU) determine the parameterization of the model:

1. The parameter $VARS\left(i\right)$ determines whether there is variety-scaling with $VARS\left(i\right) = 1$ corresponding with variety scaling. Hence, in both the Ethier-Krugman and the Melitz model this parameter is equal to 1 and in the Armington moel it is equal to 0.

2. $ETK\left(i\right)$ is a dummy variable indicating that the sector is Ethier-Krugman. We need this dummy variable for the model with the love-of-variety term, M_{is}, and for the trade decomposition. Equivalence between Melitz under granularity and Ethier-Krugman breaks

Name		Min	Max	Use	ARM	ETK	MEL
$VARS$		0	1	Variety scaling	0	1	1
ETK		0	1	Ethier-Krugman	0	1	0
$GRAN$	ξ	0	1	Granularity	1	1	< 1
$ETIL$	$\varepsilon^{v,ta}$	–	–	Tariff elasticity			
$ETRA$	$\varepsilon^{v,\tau}$	–	–	Trade elasticity			
$CATA$		0	1	Dummy to switch between $\varepsilon^{v,ta}$ and $\varepsilon^{v,\tau}$			
$PRSD$	υ	1	–	Ratio σ and ρ			
NU	ν	0	1	Love-of-variety			

Table 6: Parameterization of the four models

down in this case. Moreover, the decomposition of the value of trade into intensive, extensive, and compositional margin is not identical under Melitz approaching granularity and under Ethier-Krugman.

3. $GRAN\,(i)$ is the degree of granularity introduced in equation (19). To model a sector as either Armington or Ethier-Krugman, $GRAN\,(i)$ should be set equal to 1.

4. $ETIL\,(i)$ is the estimated tariff elasticity, the elasticity of the value of trade with respect to the power of the tariff.

5. $ETRADE\,(i)$ is the estimated trade elasticity, the elasticity of the value of trade with respect to iceberg trade costs.

6. $CATA\,(i)$ is a dummy variable indicating whether the model is calibrated to the tariff elasticity ($CATA\,(i) = 1$) or the the trade elasticity ($CATA\,(i) = 0$).

7. $PRSD\,(i)$ is measure for the degree of nestedness of preferences equal to $ESUBM\,(i)\,/ESUBD\,(i)$. The lower-nest substitution elasticity between varieties from different sourcing countries, $ESUBM\,(i)$, is determined by the estimated tariff or trade elasticity and the degree of granularity. Hence, $PRSD\,(i)$ determines ρ_i ($ESUBD\,(i)$) and a larger $PRSD\,(i)$ corresponds with a smaller upper-nest elasticity ρ_i (between domestic and imported varieties).

8. $NU\,(i)$ determines the strength of love of variety. $\nu_i = 1$ corresponds with normal CES preferences and $\nu_i = 0$ completely switches off love of variety.

Four behavioral parameters in the code are affected by the parameters in 6. In the Armington and Ethier-Krugman model we need values for the substitution elasticities parameters, σ_i and ρ_i, and the love of variety parameter, ν_i. In the Melitz model we also need values for the shape parameter, θ_i. These parameters correspond in the code respectively with *ESUBM(i)*, *ESUBD(i)*, *NU(i)*, and *THETA(i)*. From the empirics we have estimates for the tariff elasticity $\varepsilon_i^{v,ta}$ or the trade elasticity $\varepsilon_i^{v,\tau}$ and the degree of granularity ξ_i, defined in the Melitz model as:[46]

$$\varepsilon_i^{v,ta} = \theta_i + 1 + \frac{\theta_i - \sigma_i + 1}{\sigma_i - 1} \tag{17}$$

$$\varepsilon_i^{v,\tau} = \theta_i \tag{18}$$

$$\xi_i = \frac{\sigma_i - 1}{\theta_i} \tag{19}$$

[46] The tariff elasticity is derived in Subsection 7.1.

Name		Meaning	ARM	ETK	MEL
$THETA$	θ	Shape parameter Pareto distribution	$-$	$-$	$\varepsilon_{v,ta} - \frac{1}{\xi}$
$ESUBM$	σ	Substitution elasticity between imports	$\varepsilon^{v,ta}$	$\varepsilon^{v,ta}$	$\xi * \varepsilon^{v,ta}$
$ESUBD$	ρ	Subst. elasticity imports/domestic	$\varepsilon^{v,ta}/\upsilon$	$\varepsilon^{v,ta}/\upsilon$	$\xi * \varepsilon^{v,ta}/\upsilon$
NU	ν	Strength love-of-variety	ν	ν	ν

Table 7: Parameterization of the four models

We can thus express θ_i and σ_i as a function of $\varepsilon_i^{v,ta}$ and ξ_i as follows if we calibrate to the tariff elasticity:

$$\sigma_i = \xi_i * \varepsilon_i^{v,ta} \tag{20}$$

$$\theta_i = \varepsilon_i^{v,ta} - \frac{1}{\xi_i} \tag{21}$$

In the Armington and Ethier-Krugman model the tariff elasticity $\varepsilon_i^{v,ta}$ is equal to the substitution elasticity σ_i with $\xi_i = 1$.

If we calibrate to the trade elasticity, we get:

$$\sigma_i = \xi \varepsilon_i^{v,\tau} + 1 \tag{22}$$

$$\theta_i = \varepsilon_i^{v,\tau} \tag{23}$$

In the Armington and Ethier-Krugman model the trade elasticity $\varepsilon_i^{v,\tau}$ is equal to $\sigma_i - 1$. We allow for calibration to both the trade and tariff elasticity, since some researchers have estimated tariff elasticities and others might have estimated trade elasticities.

In the non-nested version of the model $\rho_i = \sigma_i$ and in the nested version $\rho_i < \sigma_i$. The love of variety parameter ν_i governs the strength of love of variety. We summarize the relation between the parameters appearing in the code and the parameters of the parameter file for calibration to the tariff elasticity in Table 7. The table shows the values for *ESUBM(i)*, *ESUBD(i)*, *NU(i)*, and *THETA(i)* implied by the values set in the parameter file.

6.6 Margin decomposition of trade

As disussed, in the Melitz model there are three margins, the intensive margin, the extensive margin, and the compositional margin; in the Ethier-Krugman model only the first two margins are operative; and in the Armington mode only the intensive margin is operative. We first present the margin decomposition in the Melitz model and then go into the decomposition in the Ethier-Krugman model. Total trade flows as measured in cif-terms, inclusive of bilateral import tariffs, but exclusive of group-specific importer tariffs, v_{irs}, can be written as the number of varieties, N_{irs}, times the average revenues exclusive of group-specific tariffs, $\widetilde{\overline{r}}_{irs}$:

$$v_{irs} = N_{irs}\widetilde{\overline{r}}_{irs} = N_{irs}\frac{1}{1 - G\left(\varphi_{irs}^*\right)} \int_{\varphi_{irs}^*}^{\infty} \overline{r}_{irs}\left(\varphi\right) g\left(\varphi\right) d\varphi \tag{24}$$

Log differentiating equation (24) on the RHS and LHS wrt to the endogenous variables gives:

$$d\ln V_{irs} = d\ln N_{irs} + N_{irs}\frac{1}{1 - G\left(\varphi_{irs}^*\right)} \int_{\varphi_{irs}^*}^{\infty} d\ln \overline{r}_{irs}\left(\varphi\right) \frac{r_{irs}\left(\varphi\right)}{r_{irs}\left(\widetilde{\varphi}\right)} g\left(\varphi\right) d\varphi$$
$$+ \frac{\partial \ln\left(1 - G\left(\varphi_{irs}^*\right)\right)}{\partial \ln \varphi_{irs}^*} d\ln \varphi_{irs}^* \left(\frac{\overline{r}_{irs}\left(\varphi_{irs}^*\right)}{\overline{r}_{irs}\left(\widetilde{\varphi}_{irs}\right)} - 1\right) \tag{25}$$

The first term represents the extensive margin, EM, i.e. the change in the mass of firms. The second term is the intensive margin, IM, so the change in sales of already exporting firms, not changing the cutoff productivity yet. The third term is the compositional margin, CM, expressing the change in export sales, because of a change in the cutoff productivity and thus in the composition of firms exporting.

We can determine the extensive margin from the fact that in steady state the number of firms exiting (the number of varieties, N_{irs}, times the death probability) is equal to the number of potential entrants, NE_{ir}, times the probability of entry, $1-G_i\left(\varphi^*_{irs}\right)$. Reorganized this gives:

$$N_{irs} = \frac{\left(1-G_i\left(\varphi^*_{irs}\right)\right)NE_{ir}}{\delta} = \left(\frac{\kappa_{ir}}{\varphi^*_{irs}}\right)^{\theta_i}\frac{NE_{ir}}{\delta} \tag{26}$$

The second equality sign follows from imposing the Pareto distribution (equation (12)). Hat differentiating equation (26) we can write the extensive margin as follows:

$$EM_{irs} = d\ln N_{irs} = -\theta_i\widehat{\varphi^*_{irs}} + \widehat{NE_{ir}} \tag{27}$$

To express the compositional margin, CM, we recognize that the ratio of average revenues and cutoff revenues is proportional to the ratio of cutoff productivities, $\frac{\overline{r}_{irs}\left(\varphi^*_{irs}\right)}{\overline{r}_{irs}\left(\widetilde{\varphi}\right)} = \left(\frac{\varphi^*_{irs}}{\widetilde{\varphi}_{irs}}\right)^{\frac{1}{\sigma-1}}$. Under the Pareto distribution the average productivity is proportional to the cutoff productivity, $\widetilde{\varphi}_{irs} = \left(\frac{\theta_i}{\theta_i-\sigma_i+1}\right)^{\frac{1}{\sigma_i-1}}\varphi^*_{irs}$. Combining these two facts, the compositional margin can be written as:

$$CM_{irs} = -\theta_i\widehat{\varphi^*_{irs}}\left(\frac{\theta_i-\sigma_i+1}{\theta_i}-1\right) = \left(\sigma_i-1\right)\widehat{\varphi^*_{irs}} \tag{28}$$

Comparing the expressions for the extensive and compositional margin in equations (27) and (28), we see that the terms in φ^*_{irs} in both expressions cancel out if the firm size distribution moves to granularity ($\theta_i = \sigma_i - 1$). Hence, only the number of entrants part of the extensive margin would remain in place. This term is only non-zero in a setting with multiple sectors and/or endogenous factor supply, such that the number of input bundles per sector can change.

Finally, we can elaborate on the intensive margin, IM, using the expression for revenues in Appendix C (equation (C.12)):

$$\begin{aligned} IM_{irs} &= \int\limits_{\varphi^*_{irs}}^{\infty} d\ln\left(\left(\frac{\frac{\sigma_i}{\sigma_i-1}ta_{irs}\tau_{irs}p^{cif}_{irs}}{\varphi}\right)^{1-\sigma_i}\sum_{ag}M_{is}^{\nu_i-1}\left(\frac{P^{ag}_{is}}{ta^{so,ag}_{is}p^{so}_{is}}\right)^{\rho_i-1}\frac{\left(p^{so}_{is}\right)^{\sigma_i-1}E^{ag}_{is}}{ta^{so,ag}_{is}}\right)\frac{g\left(\varphi\right)}{1-G\left(\varphi^*_{irs}\right)}d\varphi \\ &= \left(1-\sigma_i\right)\left(\widehat{\tau_{irs}}+\widehat{ta_{irs}}+\widehat{p^{cif}_{irs}}\right) \\ &+ \sum_{ag}\frac{p^{so}_{is}q^{so,ag}_{is}}{\sum\limits_{ag'}p^{so}_{is}q^{so,ag'}_{is}}\left(\left(\nu_i-1\right)\widehat{M_{is}}+\left(\rho_i-1\right)\widehat{P^{ag}_{is}}+\left(\rho_i-\sigma_i\right)\widehat{p^{so}_{is}}+\widehat{E^{ag}_{is}}-\rho_i\widehat{ta^{ag}_{is}}\right) \end{aligned} \tag{29}$$

Under Armington only the intensive margin is operative. Under Ethier-Krugman both the extensive and the intensive margin are operative with the following straightforward decomposition:

$$d\ln V_{irs} = d\ln N_{ir} + d\ln\overline{r}_{irs} \tag{30}$$

7 Calibration of the firm heterogeneity model

Table 6 shows that we need values for four new parameters in the model, the tariff elasticity, $\varepsilon^{v,ta}_i$, the degree of granularity, ξ_i, the degree of nested preferences, υ, and the strenght of love of variety, ν. The latter variable is set equal to 1, thus imposing standard CES preferences.

The degree of granularity is taken from the literature. We work with a degree of granularity of 5/6 in all sectors, thus setting it in between the value chosen by Caliendo et al. (2017) and full granularity. The degree of nested preferences, σ_i/ρ_i, is set equal to 1, as motivated below. We could also calibrate to the trade elasticity, $\varepsilon_i^{v,\tau}$, instead of the tariff elasticity. Since most estimates at the sectoral level on trade responsiveness to costs seems to focus on the tariff elasticity (Aichele et al. (2014b), Egger et al. (2015b), Caliendo and Parro (2015), and Spearot (2016) for example estimate tariff elasticities at the sectoral or product level), we concentrate here on calibration to the tariff elasticity, also discussing the possibility of calibration to the trade elasticity.

Before going into estimation of the tariff elasticity and calculation of the ad valorem equivalent of NTMs based on gravity estimation, we observe that we do not need explicit values for the size of fixed costs. Iceberg trade costs together with fixed costs are assumed implicitly to be such that the baseline import shares are equal to actual import shares. So, the size of fixed trade costs does not matter in the model. Bekkers and Francois (2018) discuss further how this approach to fixed costs compares with the approach in Balistreri and Rutherford (2011) where fixed costs are explicitly estimated.

7.1 Tariff elasticities, trade elasticities, and AVEs of NTMs

We can write the value of trade (net of bilateral tariffs), $v_{irs} = \frac{1}{ta_{irs}} p_{irs} q_{irs}$, in the Armington and Ethier-Krugman model on the one hand and in the Melitz model on the other hand, focusing on the differences in the bilateral term. Substituting the expressions for t_{irs} in Armington/Ethier-Krugman, $t_{irs} = \tau_{irs}$, and in Melitz, t_{irs} as defined in equation (15), into the expression for demand in (4) gives:

$$v_{irs}^{arm,etk} = \left(\tau_{irs} te_{irs} \left(1 + itm_{irs}\right)\right)^{1-\sigma_i} ta_{irs}^{-\sigma_i} \left(\frac{e_{is}^m p_{is}^m}{tp_{ir} p_{ir}^{ib} c_{ir}^m} \right)^{\sigma_i - 1} E_{is}^m \tag{31}$$

$$v_{irs}^{mel} = \left(\tau_{irs} te_{irs} \left(1 + itm_{irs}\right)\right)^{-\theta_i} ta_{irs}^{-\left(\theta_i + 1 + \frac{\theta_i - \sigma_i + 1}{(\sigma_i - 1)}\right)} f_{irs}^{-\frac{\theta_i - \sigma_i + 1}{\sigma_i - 1}} \left(\frac{e_{is}^m p_{is}^m}{tp_{ir} p_{ir}^{ib} c_{ir}^m} \right)^{\sigma_i - 1} E_{is}^m \tag{32}$$

We have used the following expression for the cif-price p_{irs}^{cif}, $p_{irs}^{cif} = te_{irs} tp_{ir} p_{ir}^{ib} \left(1 + itm_{irs}\right)$ with te_{irs} the export tax and itm_{irs} the international transport margin, $itm_{irs} = \frac{p_{ijr}^{ts}}{tp_{ir} p_{ir}^{ib} a_{ijr}^{ts}}$. The coefficient on tariffs features an additional term in the Melitz model. This follows from the assumption that tariffs are paid on the marked-up prices (called revenue-shifting tariffs in for example Costinot and Rodríguez-Clare (2013) and Caliendo et al. (2017)). Therefore, the zero cutoff profit condition is affected differently by tariffs than by the iceberg trade costs and the export taxes, implying a different coefficient on the gravity equation. Further discussion is in Bekkers and Francois (2018).

The empirical gravity equation can be written as follows:[47]

$$v_{irs}^{emp} = \exp\left(-\varepsilon_i^{v,ta} \ln ta_{irs} - \varepsilon_i^{v,te} \left(te_{irs} \left(1 + itm_{irs}\right)\right) + a_i^{tcc} \ln tcc_{irs} + a_i^{tcd} tcd_{irs} + \psi_{ir} + \eta_{is} + \varepsilon_{irs}\right) \tag{33}$$

Exporter and importer fixed effects, ψ_{ir} and η_{is}, capture the exporter and importer specific terms, respectively $\left(tp_{ir} p_{ir}^{ib} c_{ir}^m\right)^{1-\sigma_i}$ and $\left(e_{is}^m p_{is}^m\right)^{\sigma_i - 1} E_{is}^m$. Comparing equations (31)-(33) shows that the tariff elasticity, $\varepsilon_i^{v,ta}$, (based on the value of trade net of import tariffs) is equal to σ_i in the Ethier-Krugman/Armington model and equal to $\left(\theta_i + 1 + \frac{\theta_i - \sigma_i + 1}{\sigma_i - 1}\right)$ in the Melitz model. Equations (31)-(33) show as well that the trade elasticity, the elasticity of v_{irs}^{emp} with respect

[47] We include a minus sign before the tariff and trade elasticities, $\varepsilon_i^{v,ta}$ and $\varepsilon_i^{v,\tau}$ respectively, implying that these elasticities are positive.

to iceberg trade costs, τ_{irs}, is θ_i in the Melitz model and $\sigma_i - 1$ in the Armington and Ethier-Krugman models. In Bekkers and Francois (2018) we estimate the tariff elasticities based on GTAP10 trade data. In this report we use the estimates in the GTAP database, assuming that the substitution elasticities, $ESUBM\left(i\right)$, are based on estimated tariff elasticities. If the GTAP elasticities are used, the tariff elasticity, $\varepsilon_i^{v,ta}$, should be set equal to the substitution elasticities between varieties from different countries, $ESUBM\left(i\right)$.[48]

We include continuous measures of bilateral NTMs denoted by $ntmc_{irs}$ (trade costs continuous), and dummy measures of NTMs like the the number of SPS-measures or the trade facilitation index score, denoted by the vector $ntmd_{irs}$ (trade costs dummy) in the gravity equation. Turning to counterfactual experiments these measures can be mapped into their ad valorem equivalent (AVE) to determine the effects of a change in these measures. The AVE of a measure is defined as the equivalent ad valorem trade cost of a 1% change of the measure or in case of a dummy variable of a change of the measure from 0 to 1:

$$AVE^{ntmc} = \frac{d\ln\tau_{irs}}{d\ln ntmc_{irs}} \tag{34}$$

$$AVE^{ntmd} = \frac{\tau_{irs}\left|ntmd_{irs} = 1 - \tau_{irs}\right|ntmd_{irs} = 0}{\tau_{irs}\left|ntmd_{irs} = 0\right.} \tag{35}$$

The most common approach in the literature to determine the AVE is through the estimation of a gravity equation. We show now how equations (31)-(33) can be combined to express the AVE of a continuous variable as a function of the estimated gravity coefficients (using $\frac{d\ln v_{irs}}{d\ln tcc_{irs}} = \frac{d\ln v_{irs}}{d\ln\tau_{irs}}\frac{d\ln\tau_{irs}}{d\ln ntmc_{irs}}$):[49]

$$AVE_{arm,etk}^{ntmc} = \frac{a_i^{ntmc}}{1-\sigma_i} = -\frac{a_i^{ntmc}}{\varepsilon_i^{v,\tau}} = -\frac{a_i^{ntmc}}{\varepsilon_i^{v,ta}-1} \tag{36}$$

$$AVE_{mel}^{ntmc} = \frac{a_i^{ntmc}}{-\theta_i} = -\frac{a_i^{ntmc}}{\varepsilon_i^{v,\tau}} = -\frac{a_i^{ntmc}}{\varepsilon_i^{v,ta}-1/\xi_i} \tag{37}$$

For a dummy variable we get (using for example for the Melitz model $\frac{v_{irs}|ntmd_{irs}=1}{v_{irs}|ntmd_{irs}=0} = \left(\frac{\tau_{irs}|ntmd_{irs}=1}{\tau_{irs}|ntmd_{irs}=0}\right)^{-\theta_i} = \exp\left(a_{tcd}ntmd_{irs}\right)$):

$$AVE_{arm,etk}^{ntmd} = \exp\left(\frac{a_i^{ntmd}}{1-\sigma_i}\right) - 1 = \exp\left(-\frac{a_i^{ntmd}}{\varepsilon_i^{v,\tau}}\right) = \exp\left(-\frac{a_i^{ntmd}}{\varepsilon_i^{v,ta}-1}\right) - 1 \tag{38}$$

$$AVE_{mel}^{ntmd} = \exp\left(\frac{a_i^{ntmd}}{-\theta_i}\right) - 1 = \exp\left(-\frac{a_i^{ntmd}}{\varepsilon_i^{v,\tau}}\right) = \exp\left(-\frac{a_i^{ntmd}}{\varepsilon_i^{v,ta}-1/\xi_i}\right) - 1 \tag{39}$$

So to calculate the AVE in the Melitz model based on the tariff elasticity an estimate of the degree of granularity ξ_i is required. We have included the AVE based on both the estimated tariff and trade elasticities , respectively $\varepsilon_i^{v,ta}$ and $\varepsilon_i^{v,\tau}$. In the Armington and Ethier-Krugman models the tariff elasticity (based on cif prices net of tariffs) is equal to the trade elasticity plus one, but in the Melitz model the tariff elasticity features an additional term. Therefore, the AVE calculated from the same estimated coefficient on an NTM, a_i^{tcd}, is identical in the Armington/Ethier-Krugman models and the Melitz model when the trade elasticity is used to convert the trade measure into the AVE. But the AVE is different when the tariff elasticty is used to convert the NTM.

[48] Also other empirically estimable elasticities could be used. It is important, however, that the model is calibrated to the empirically estimated elasticities. So, if for example the estimated tariff elasticities from Spearot (2016) are used, which give the shape parameters θ_i in the Melitz-Ottaviano model, then these estimates should not be used as measures for the shape parameters θ_i in the Melitz model. They should be used to identify the tariff elasticities instead as well and from this the shape parameters in the Melitz model can be identified in turn.

[49] The alternative approach to determine AVEs is the price approach, attributing price differences to the presence of AVEs (see for example Cadot and Gourdon (2016))

In the Melitz model we have to take into account that an NTM can affect trade flows both through iceberg and through fixed trade costs. We can define the fixed cost equivalents (FCEs) of an NTM as follows:

$$FCE_{mel}^{ntmc} = \frac{-a_i^{ntmc}}{-\frac{\theta_i-\sigma_i+1}{\sigma_i-1}} = \frac{a_i^{ntmc}}{\frac{1}{\xi_i}-1} \tag{40}$$

$$FCE_{mel}^{ntmd} = \exp\left(\frac{a_i^{ntmd}}{\frac{1}{\xi_i}-1}\right) - 1 \tag{41}$$

Equation (40) indicates that FCE_{mel}^{ntmc} would go to infinity when the firm size distribution tends to granularity (with $\xi_i = 1$). The reason is that fixed exporting costs should not have any effect on trade flows under granularity (with the destination-specific extensive margin and the compositional margin cancelled out against each other) thus implying that the effect of fixed trade costs should be zero.

The trade cost shifter, t_{irs}, as defined in equation (15) is proportional with $\left(\tau_{ij}^{\theta} f_{ij}^{\frac{\theta-\sigma+1}{\sigma-1}}\right)^{\frac{1}{\sigma-1}}$. Therefore, the elasticity of t_{irs} with respect to the NTM, $ntmc_{irs}$ is equal to $\frac{a_i^{ntmc}}{\sigma_i-1}$ both when $ntmc_{irs}$ affects iceberg trade costs and when it affects fixed trade costs. So for the total effect of a change in the NTM, $ntmc_{irs}$, in a counterfactual experiment it does not matter whether it affects iceberg or fixed trade costs. Only for the margin decomposition it does matter how the change is operationalized. In general though it will be hard to determine conceptually whether NTMs affect trade flows through iceberg or through fixed trade costs. For example, it is likely that NTMs like TBT-measures or SPS-measures affect trade flows through both. It is less costly to import into countries with less SPS-measures, both because the variable costs of exporting are lower and because the fixed costs for firms are lower. It is hard to find measures that only affect one of the two trade costs. Our framework shows, however, that only for the decomposition of the different trade margins it is necessary to identify the type of trade costs affected (fixed or iceberg) by a generic NTM.

8 Counterfactual experiments

We conduct experiments with reductions in NTMs through reductions in iceberg and fixed trade costs to illustrate our model. We do this in a setting with 11 countries, 11 sectors, and 6 sectors of production based on the GTAP10 data for 2014. An overview of the aggregation can be found in Table D1. The parameters are as discussed in the previous section. We set the values for the tariff elasticity, $\varepsilon_i^{v,ta}$, and trade elasticity, $\varepsilon_i^{v,\tau}$, equal to respectively *ESUBM(i)* and *ESUBM(i)-1*, thus using the parameter values implied by the standard GTAP model with Armington preferences. We do this for the three different models. We conduct three sets of trade cost experiments. First, we we start with a plain identical percentage change in iceberg trade costs in all sectors equal to 2%, thus abstracting from possible reasons for different sizes of shocks in the different models. For comparison, we also implement a shock to fixed trade costs in the Melitz model. To get a seemingly comparable shock in size to the 2% shock to iceberg trade costs, we reduce fixed trade costs by 28.5%. This number is based on the fact that the elasticity of generalized trade costs with respect to iceberg trade costs and fixed trade costs are respectively $\frac{\theta_i}{\sigma_i-1}$ and $\frac{\theta_i-\sigma_i+1}{(\sigma_i-1)^2}$. Based on a trade weighted average tariff elasticity of 7 and a degree of granularity of 0.83, we get that a fixed trade cost reduction of 56.6% is expected to be roughly equivalent to an iceberg trade cost shock of 2%.[50]

Second, we implement a reduction in iceberg trade costs corresponding with a coefficient of -0.1 for a_i^{ntmd} and the tariff elasticity, $\varepsilon_i^{v,ta}$, to transfer a_i^{ntmd} into the corresponding AVE and

[50] $56.6\% = \widehat{f} = \frac{\theta(\sigma-1)}{\theta-\sigma+1}\widehat{\tau} = \frac{\xi\varepsilon^{v,ta}-1}{1-\frac{1}{\xi}}\widehat{\tau} = \frac{0.83*7-1}{1-1/0.83} * 2\%$

Table 8: Changes in world equivalent variation (WEV) in millions of dollars in different models and for different shocks

Experiment	Calibration parameter	Model	Shock variable	Size shock	Change WEV
1	Tariff elasticity $\varepsilon_i^{v,ta}$	Armington	τ_{irs}	-2%	550175
		Ethier-Krugman	τ_{irs}	-2%	581626
		Melitz	τ_{irs}	-2%	589167
		Melitz	f_{irs}	-56.9%	1007820
2	Tariff elasticity $\varepsilon_i^{v,ta}$	Armington	a_i^{tcd}	-0.1	524617
		Ethier-Krugman	a_i^{tcd}	-0.1	541857
		Melitz	a_i^{tcd} (through τ_{irs})	-0.1	571887
		Melitz	a_i^{tcd} (through f_{irs})	-0.1	571887
3	Trade elasticity $\varepsilon_i^{v,\tau}$	Armington	a_i^{tcd}	-0.1	524617
		Ethier-Krugman	a_i^{tcd}	-0.1	541857
		Melitz	a_i^{tcd} (through τ_{irs})	-0.1	545907
		Melitz	a_i^{tcd} (through f_{irs})	-0.1	545907

Notes: In experiments 1 and 2 the model is calibrated to the tariff elasticity and in experiment 3 to the trade elasticity. Experiment 1 contains uniform shocks to iceberg and fixed trade costs, whereas experiments 2 and 3 contain uniform shocks in the estimated trade cost dummy, tcd_i, from zero to one with different implied shocks to icebeg and fixed trade costs, depending on respectively tariff and trade elasticities in experiments 2 and 3. The implied changes in iceberg trade costs in different models are calculated as explained in the text, based on equations (38), (39), and (41).

iceberg trade costs shock based on equations (38)-(39). We also implement this shock through a reduction in fixed trade costs in the Melitz model employing equations (41). $a_i^{tcd} = -0.1$ could be for example the coefficient on a dummy variable for the presence of an FTA between countries. Since the elasticities vary across sectors, shocks also vary across sectors. Furthermore, the size of the shock differs between the Melitz model on the one hand and the Armington/Ethier-Krugman models on the other hand. The reason is that the denominators in calculating the AVEs in equations (38)-(39) differ between the models. The denominator is smaller in the Melitz model for the same tariff elasticity, thus implying larger trade cost shocks. Given that the gravity equations are observationally equivalent for the different models, we should employ the same tariff elasticity. The tariff elasticity in the Melitz model contains an additional positive term relative to the trade elasticity, whereas this is not the case in the Armington/Ethier-Krugman models. Therefore, transforming a trade cost measure which is part of iceberg trade costs leads to a larger AVE in the Melitz model than in the other models.

Dixon et al. (2016) also implement different shocks in the Melitz and Armington model to make the models comparable (besides working with different substitution elasticities). They argue that a correct comparison of the two models should impose that the trade volume response to a tariff reduction is identical in the different models and therefore elasticities and shocks should be adjusted in the comparison, leading to smaller shocks in the Melitz model. We argue that the starting point should be the empirically estimated tariff elasticities and the estimated coefficients on trade policy measures, which are to be changed in a counterfactual exercise. The estimated tariff elasticities and policy measure coefficients should be identical across models. Subsequently the structure of the different models should be employed to calculate the shocks to trade costs and the behavioral parameters, the substitution elasticity, σ_i, and the shape parameter of the Pareto distribution, θ_i. Since the trade structure of the two models is different, trade volume responses can then also be different.

As a third set of experiments, we use the same coefficient $a_i^{tcd} = -0.1$, but employ the trade elasticity, $\varepsilon_i^{v,\tau}$, to calculate the corresponding AVE. In this case the size of the shocks is identical in the different models.

Table 8 displays the changes in the total equivalent variation in all countries (wev) for the three sets of experiments and the three models. Three conclusions can be drawn from the table. First, the different trade structures can be ranked in terms of the size of welfare effects as in previous work: the largest welfare gains occur in the Melitz model, followed by the Ethier-Krugman and Armington model. The differences are relatively modest. The welfare gains in the Melitz model are about 10% larger than in the Armington model, but the differences with the Ethier-Krugman model are more modest, in the range of 1%-2%. The differences are much smaller than in some of the previous literature. However, the experiments conducted do not include features which are likely to drive the large effects in the Melitz model, endogenous factor supply and different bundles in fixed and variable costs in respectively Balistreri et al. (2010b) and Akgul et al. (2016).

Second, Table 8 shows that the way equality of shocks is operationalized has some impact on the welfare effects. In particular, the difference between the Melitz welfare effects and the Ethier-Krugman welfare effects are largest when identical shocks to trade cost measures are converted into ad valorem equivalents based on the model calibrated using tariff elasticities. Third, as expected, the total effects are identical for shocks to fixed export costs and shocks to iceberg trade costs. But we see that the rough conversion of the iceberg trade cost reduction into the reduction in fixed export costs, based on the trade-weighted average tariff elasticity and degree of granularity was not very successful. A shock to fixed export costs of 56.6% has a much lager impact than the 2% shock to iceberg trade costs.

Table 9: Decomposition of welfare effects in millions of dollars

Shock variable	Model	Regions	Welfare (EV)	Allocative efficiency	Investment -savings price	Terms of Trade	Pure iceberg trade costs	Importer productivity	Domestic productivity	Importer variety	Domestic variety
		Total	550175	105653	11	-200	444711	0	0	0	0
Iceberg trade costs	Armington	EAA	139036	41567	-2332	14530	85271	0	0	0	0
		EU	176353	33059	-728	16494	127528	0	0	0	0
		Total	581626	111929	3	-187	446617	0	0	6485	16778
Iceberg trade costs	Ethier-Krugman	EAA	140804	44676	-1152	12673	85565	0	0	144	-1101
		EU	185280	33212	-462	13251	127818	0	0	-1464	12924
		Total	589167	114158	0	-195	446235	-260395	272550	326242	-309429
Iceberg trade costs	Melitz	EAA	141354	44670	-1005	12150	85453	-61391	57619	74261	-70403
		EU	190929	34562	-455	13021	127662	-73579	71813	86898	-68991
		Total	1007820	187556	-13	-387	0	-4442176	551853	5378431	-667510
Fixed trade costs	Melitz	EAA	209481	68177	-77	9879	0	-786514	105592	948763	-136363
		EU	352469	62683	-577	18748	0	-1350459	158666	1625096	-161744

The total welfare effect, EV, is decomposed for experiment 1 with uniform reductions in iceberg and fixed trade costs

Next, we turn to the decomposition of the welfare effects for the first set of experiments with identical reductions in iceberg and fixed trade costs in the three models in Table 9. We see that the direct impact of reductions in iceberg trade costs (the term "pure iceberg trade costs") is very similar across the three models. The additional welfare gains under Ethier-Krugman and Melitz are partially driven by larger allocative efficiency effects, but mostly by the additional terms importer and domestic productivity and importer and domestic variety. We see that in the Melitz model the increase in domestic productivity is somewhat larger than the fall in importer productivity. The some holds for changes in the number of varieties. The positive contribution to welfare of an increase in the number of domstic varieties is somewhat larger than the negative contribution of domestic varieties. In the Ethier-Krugman model we see that changes in both the number of domestic and imported varieties are positive. The reason for this difference with the Melitz model is that in the Melitz model the share of firms involved in international trade changes. In the Ethier-Krugman model instead the number of firms from a certain country is identical for all destination markets by the absence of destination-specific fixed costs.

The decomposition for the shock to fixed costs deserves additional explanation. The pure iceberg trade costs term is zero, as obviously there is no shock to iceberg trade costs. However, we also did not include a separate term for the change in fixed trade costs. The reason is that the effects of changes in fixed trade costs all run through changes in the number of varieties and productivity. We observe that the negative contribution of the change in importer productivity is an order larger than the positive contribution of the change in domestic productivity. At the same time the positive contribution of the change in imported varieties is an order larger than the negative contributio of the change in the number of domestic varieties. A reduction in fixed trade costs provokes a huge increase in the number of imported varieties in the model, which harms welfare through the reduction in average productivity of exporting firms (a compositional margin effect) and raises welfare through the increase in the number of imported varieties available. Reductions in fixed costs mainly lead to an increase in the number of small firms able to export. On net the contribution of the increase in the number of firms exporting is positive.

Table 10: Changes in the value of trade in millions of dollars along the different trade margins

Shock variable	Model	Regions	Margins			
			Intensive	Extensive	Compositional	Total
		Total	34058	0	0	34058
Iceberg trade costs	Armington	EAA	15165	0	0	15165
		EU	9684	0	0	9684
		Total	42080	5589	0	47668
Iceberg trade costs	Ethier-Krugman	EAA	16320	-29	0	16291
		EU	11492	-1302	0	10190
		Total	31742	59277	-41542	49477
Iceberg trade costs	Melitz	EAA	12764	17408	-14395	15777
		EU	8637	11376	-10489	9523
		Total	898728	-86636	-724526	87568
Fixed trade costs	Melitz	EAA	197346	-13596	-162817	20934
		EU	241575	-22090	-202180	17306

Changes in the value of trade are decomposed for experiment 1 with uniform reductions in iceberg and fixed trade costss

Table 10 decomposes the change in the value of trade into the three margins introduced before, the intensive, extensive, and compositional margin. Three things stand out from the table. First, the total change in the world value of trade for an identical shock to iceberg trade costs of 2% is largest in the Melitz model, followed by the Ethier-Krugman model, and then the Armington model.[51] We do not take into account the changes in the Melitz model provoked by shocks to fixed costs, since the total welfare effects are also much larger for this shock due to the size of the shock. Second, the intensive margin is smallest in the Melitz model, which is compensated for by a large value of the extensive margin relative to the compositional margin. Third, we see that the contribution of the extensive margin in the Ethier-Krugman model is an order smaller than in the Melitz model. In the Ethier-Krugman model the extensive margin is exclusively driven by changes in the number of entering firms to the market, whereas in the Melitz model also changes in the number of firms exporting to specific destinations play a role. To compare the role of entry in the two models, we could separate the extensive margin in the Melitz model into a general market entry term and an export-specific entry term.

[51] Dixon et al. (2016) have argued that a fair comparison between the three models would require an identical change in the volume of trade. As pointed out before, we argue that empirical observable elasticities should be identical. The two do not correspond, because in the Melitz model there are additional changes in the model leading to changes absorbed by the fixed effects in a gravity estimation. Imposing equal changes in trade volumes would likely imply in our model that the welfare effects under Melitz would become (much) smaller than under Armington, since changes in the value of trade in the Melitz model are almost 50% larger.

9 Conclusions

In the first part of the report we have evaluated different methods for ex ante policy assessments of NTMs, comparing ex ante CGE-studies and SG-studies on the expected effects of reductions in NTMs as a result of TTIP. CGE models are considered to be the state of the art approach in assessing trade policy in policy circles (Pelkmans et al., 2014; Mustilli, 2015), whereas they are considered obsolete among a group of academics (Caliendo and Parro, 2015) who instead prefer structural gravity models. We think that both methodological approaches have merit. The compact and more transparent nature of the SG models can be valuable, even based on a single sector, if properly executed. A more extensive model, however, with multiple sectors, multiple factors, a realistic and detailed description of taxes and subsidies, capital and imperfect competition in selected sectors has the important advantage that it generates more detailed results on different sectors and production factors, which is useful for analysts and policy makers.

There seems to be a tendency towards convergence of both literatures. CGE models increasingly use structural estimations as inputs, while structural gravity models have become more complex over time. For example, the CGE-study by Egger et al. (2015a) estimates the trade elasticities structurally, whereas the SG-model of Aichele et al. (2014a) contains multiple sectors and intermediate linkages and calibrates baseline import shares to actual import shares in deviation from earlier SG-studies with a single sector without intermediate linkages and calibration based on fitted trade costs. However, Aichele et al. (2014a) still omit important elements for trade policy analysis, such as multiple production factors, capital and imperfect competition. Multiple production factors are important to uncover possible differences in the impact on factor rewards and the inclusion of capital and imperfect competition make the models more realistic.

Comparing the assessed studies we find that both differences in the estimated trade cost reductions as a result of TTIP and in the employed economic model drive the differences in the expected economic effects across studies. The most important difference in estimation of the trade cost reductions is whether a bottom-up approach based on micro-data on NTMs or a top-down approach based on average FTA effects is chosen. The most important difference in the economic modelling is the market structure in combination with the size of the trade elasticities. With an Armington or Eaton-Kortum perfect competition setting the effects are modest, whereas a monopolistic competition setting with endogenous capital accumulation without a nested preference structure generates larger effects. With small trade cost changes (of around 3%) and an economic model generating modest effects the real income gains of TTIP are around 0.2%, whereas large trade cost reductions (of around 13%) and a model generating relatively larger effects, generate real income gains around 2% on average for the EU and the US. The much larger welfare gains generated by some studies are considered unlikely, because they are based on a simulation model with a problematic baseline calibration.

In the second part of this report we have proposed a setup to capture three trade models (Armington, Ethier-Krugman, and Melitz) in the standard trade framework of the GTAP model by including demand, supply, and trade cost shifters. We have shown how the expressions in the standard trade framework are adapted, outlined their implementation in the GTAP framework, provided intuition for the expressions, and included a detailed derivation (in the appendix). Our framework does not require solving for additional pairwise variables like the cutoff productivity and the mass of firms, keeping the dimensionality of the model limited. We have also extended the standard welfare decomposition in the GTAP framework adding terms for changes in domestic and imported average productivity and numbers of varieties.

We have presented the gravity equations in the different trade structures and discussed ad valorem equivalents based on gravity estimates of trade policy measures. We have used these estimates to conduct experiments of reductions in iceberg and fixed trade cost reductions with a medium-sized model with 11 countries, 11 sectors, and 6 factors of production. The simulations show that the welfare effects are largest in the Melitz model, followed by the Ethier-Krugman, and Arrmington model, although the differences are modest. In our companion report, Bekkers and Francois (2018), we discuss into much more detail which factors have an impact on differences in outcomes of counterfactual experiments in the different models.

Research on the following three sets of topics would be highly useful for (applied) researchers trying to predict the expected effects of changes in NTMs through FTAs. First, more research is needed on the NTM effects of FTAs and accordingly, robustness analysis should be conducted using alternative estimations for NTMs. Second, more research on the spillover effects of FTAs is needed, since little is known about this issue, both empirically and theoretically. Third, a more in-depth evaluation of the impact of differences in modelling setups would be very useful, exploring different types of counterfactual experiments. What is the impact of multiple sectors, multiple factors, monopolistic competition and different ways to include capital? Our work in Section 4 and the work by Costinot and Rodríguez-Clare (2013) provides valuable insights in this respect, but more questions should be answered. In particular, the impact of modelling features for different types of counterfactual experiments (unilateral, bilateral, multilateral; changes in tariffs and non-tariff measures) should be evaluated.

Our current work on the role of firms in evaluating the effects of NTMs in CGE-models could be extended as well into at least three directions. First, we could impose country-specific values for the substitution elasticities and the trade parameters, although this obviously would also require the estimation of country-specific tariff/trade elasticities and firm size shape parameters. Second, we could extend our parsimonious setup with features addressed in the literature on firm heterogeneity like endogenous unemployment, endogenous innovation, and multinational activity. Third, we could estimate the CET-parameters governing the degree of labor immobility based on labor market data and or changes in the GTAP data over time.

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Appendix A Single sector model

We model the single sector economy both without and with intermediate linkages. Without intermediate linkages we work with the following equilibrium equations, following directly from an Armington type model as in Anderson and van Wincoop (2003):

$$w_i L_i = \sum_{j=1}^{J} (t_{ij} w_i)^{1-\sigma} P_j^{\sigma-1} (1 + D_j) w_j L_j \tag{A.1}$$

$$P_j = \left(\sum_{j=1}^{J} (t_{ij} w_i)^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \tag{A.2}$$

L_i is the fixed amount of factor inputs (also called endowments in the SG-literature), w_i the price of factor inputs, t_{ij} iceberg trade costs, σ the substitution elasticity, D_j the fixed trade deficit ratio, $D_j = \frac{E_j - w_j L_j}{w_j L_j}$ and P_j the price index. In a single sector setting without extensive margin and a fixed amount of inputs (labour) the effects of a reduction in iceberg trade costs are identical to the effects in a Krugman-type model as in Felbermayr et al. (2015).

We calibrate the model to the same data as the multi-sector and multi-factor data used for the other simulations with values aggregated to one sector and one factor of production. We calibrate trade costs as in the CGE-literature, so baseline trade costs are such that baseline import shares are equal to actual import shares. To calibrate the model to the same data as the multi-sector model we set $w_i L_i$ in the baseline equal to gross output in the data. This guarantees that total exports by country i are equal to income $w_i L_i$ in the baseline.

We model intermediates as is standard in the SG-literature and much of the new quantitative trade literature employing EHA. Gross output is a Cobb-Douglas composite of intermediate inputs and factor inputs with intermediate input bundles being identical final consumption bundles. Phrased differently, there is no difference in the import shares of final consumption and intermediate inputs. Therefore, we have the following equilibrium equations:

$$\frac{w_i L_i}{\alpha_i} = \sum_{j=1}^{J} (t_{ij} p_{Z_i})^{1-\sigma} P_j^{\sigma-1} (1 + D_j) \frac{w_j L_j}{\alpha_j} \tag{A.3}$$

$$P_j = \left(\sum_{j=1}^{J} (t_{ij} p_{Z_i})^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \tag{A.4}$$

$$p_{Z_i} = w_i^{\alpha_i} P_i^{1-\alpha_i} \tag{A.5}$$

With Z_i the quantity of gross output, p_{Z_i} the price of gross output and α_i the share of value added in gross output. We calibrate α_i to the value added share in the data.

For the calibration to fitted shares, a gravity equation with exporter and importer fixed effects is estimated with Poisson pseudo maximum likelihood (PPML), as is standard in the literature:

$$V_{ij} = \exp (T_{ij} + X_i + M_j) \varepsilon_{ij} \tag{A.6}$$

With T_{ij} a function of the bilateral observables log(distance), a border dummy, a common language dummy, a common coloniser dummy and a dummy for the existence of an FTA between country i and j. Baseline trade costs t_{ij} are calibrated to $t_{ij} = \exp \left(\widehat{T_{ij}} \right)^{\frac{1}{1-\sigma}}$ with $\widehat{T_{ij}}$ the fitted value of the gravity equation (with the coefficient for FTA fixed at 1.22, the value in Felbermayr et al. (2015).

Appendix B Capaldo (2014)

One study that gained some attention in the policy debate is Capaldo (2014). Unfortunately, this study is well below the standards of any quantitative trade model analysed so far (cf. Bauer and Erixon, 2015, for a detailed critique of the analysis)

This study uses the UN Global Policy Model, which is a macroeconomic modelling approach with a number of short-term disequilibrium features. The model has no trade elements –besides a rough use of the current account. It does not include tariffs nor any other trade costs that can be changed to simulate trade policy. Thus, it does not include the foundations for any kind of basic trade analysis. Rather, the study simply takes trade volume effects from the CEPR study and externally imposes these onto a simple macroeconomic imbalances model. As such, it does not even provide an estimate of the impact of TTIP, but an estimate of how current account changes may affect short-term macroeconomic variables.

The modelling framework, moreover, suffers from grave additional analytical problems:

- The Keynesian short-term approach argues that the EU will lose demand because of a fall in its trade surplus and given the current state of relatively low demand this will create additional unemployment rises. This is an unreasonable approach, since trade policy implicit in TTIP are long-term policies that have mainly supply-side effects that are distinctively different from changing or stabilising short-term aggregate demand (Wolf, 2015).

- Another problem with the application is that one of the model assumptions is that labour markets are rigid and slow to react to external shocks (not only in the short run but also in the long run) and as such, there is an increase in unemployment and a decrease of the labour share in production with changes to aggregate demand. Assuming that workers are not capable of reallocating between broad economic sectors in the long run is a completely unrealistic assumption. In addition, the short-term effects on employment and production generated in the model are not driven by trade policy or TTIP. The results of the model are driven by the external shock to the economy from changes in the bilateral trade balances, which is wrongly assigned to the long-term effects of TTIP.

- There is a clear internal inconsistency in the exercise. The trade flows taken from the CGE model in the CEPR study are long-term effects that are only possible with labour reallocation between sectors over several years. This is, to achieve the changes in trade flows from the CEPR study, labour *must* be reallocated between sectors. But Capaldo (2014) imposes these long-term trade flow changes in a short-term setting where labour reallocation is not possible. As such, he assumes that changes in the long-term trade imbalances will have short-term effects on aggregate demand and current employment levels, which is just a very subpar economic analysis.

To sum up, Capaldo (2014) is a technically flawed study that uses an ill-suited methodological framework to analyse the TTIP experiment. Hence, the results from this sui generis analysis are not correct.

Appendix C Derivation demand, supply, and trade cost shifter

In this appendix we derive the expressions for the demand, supply, and trade cost shifter in the Ethier-Krugman and Melitz models. To do so we write the price index in these two models, p_{is}^{ag}, as defined in equation (8) as in the standard GTAP model as in (5) and (7). The price index in the standard model is equal to the price index in the Ethier-Krugman/Melitz model if we have the following expressions:

$$\frac{p_{irs}}{e_{is}^{m}} = \frac{t_{irs}ta_{irs}p_{irs}^{cif}}{c_{ir}^{m}e_{is}^{m}} = \left(M_{is}^{\nu_i - 1} \int\limits_{\omega\in\Omega_{irs}} p^{ag,o}\left(\omega\right)^{1-\sigma_i} d\omega \right)^{\frac{1}{1-\sigma_i}} \tag{C.1}$$

$$\frac{p_{iss}^{d,ag}}{e_{is}^{d}} = \frac{tp_{is}p_{is}^{ib}}{e_{is}^{d}c_{is}^{d}} = \left(M_{is}^{\nu_i - 1} \int\limits_{\omega\in\Omega_{iss}^{d}} p^{ag,o}\left(\omega\right)^{1-\sigma_i} d\omega \right)^{\frac{1}{1-\sigma_i}} \tag{C.2}$$

We will now elaborate on the RHS of (C.1)-(C.2) for the two models. This will then give the expressions for t_{irs}, e_{is}^{so}, and c_{is}^{so}.

Appendix C.1 Ethier-Krugman Economy

To determine t_{irs}, e_{is}^{so}, and c_{ir}^{so} in the Ethier-Krugman model we rewrite the RHS of equation (C.1), recognizing that all firms (and thus all prices) are identical in this model:

$$\frac{t_{irs}ta_{irs}p_{irs}^{cif}}{c_{ir}^{m}e_{is}^{m}} = M_{is}^{\frac{\nu_i - 1}{1-\sigma_i}} N_{ir}^{\frac{1}{1-\sigma_i}} p_{irs}^{o} \tag{C.3}$$

Hence, we need to determine N_{ir} and p_{irs}^{o} in the model. To do so we combine the markup equation, the free entry condition, and factor market equilibrium, starting with the expression for firm demand.

Preferences as defined in equation (8) imply that a firm producing in country r faces the following demand in country s (since firms are identical we omit a variety or firm identifier):

$$o_{irs} = \left(M_{is}\right)^{\nu_i - 1} \left(\frac{p_{irs}^{o}}{p_{is}^{so}}\right)^{-\sigma_i} \sum_{ag} \left(\frac{ta_{is}^{so,ag}p_{is}^{so}}{p_{is}^{ag}}\right)^{-\rho_i} \frac{E_{is}^{ag}}{p_{is}^{ag}} \tag{C.4}$$

p_{irs}^{o} is the firm's price corresponding with quantity o_{irs} (exclusive of group-specific taxes $ta_{is}^{so,ag}$), p_{is}^{so} the price index of goods from source so (domestic or foreign), p_{is}^{ag} the aggregate price index for end user ag and E_{is}^{ag} its expenditures. Profits can be written as revenues minus costs:

$$\pi_{irs} = \frac{p_{irs}^{o}o_{irs}}{ta_{irs}} - \tau_{irs}\left(te_{irs}tp_{ir}b_{ir}p_{ir}^{ib} + \frac{p_{irs}^{ts}}{a_{irs}^{ts}}\right) o_{irs} - a_{ir}tp_{ir}p_{ir}^{ib} \tag{C.5}$$

This expression for profit in (C.5) implies the following standard markup pricing rule:

$$p_{irs}^{o} = \frac{\sigma_i}{\sigma_i - 1} ta_{irs}\tau_{irs}\left(te_{irs}tp_{ir}b_{ir}p_{ir}^{ib} + \frac{p_{irs}^{ts}}{a_{irs}^{ts}}\right) \tag{C.6}$$

Profits of a firm from country r can now be written as revenues divided by σ_i times ta_{irs} minus fixed costs and equalized to zero by free entry:

$$\pi_{ir} = \sum_{s=1}^{S} \frac{p_{irs}^{o}o_{irs}}{\sigma_i ta_{irs}} - a_{ir}tp_{ir}p_{ir}^{ib} = 0 \tag{C.7}$$

We can now determine the number of varieties produced in country r, N_{ir}, based on factor market equilibrium with q_{ir}^{ib} the quantity of input bundles from country r:

$$\left(\sum_{s=1}^{S} \tau_{irs}o_{irs} + a_{ir}\right) N_{ir} = q_{ir}^{ib} \tag{C.8}$$

We have to take into account the presence of transport costs, by rewriting physical output inclusive of iceberg trade costs as follows based on the markup equation in (C.6):

$$\tau_{irs}o_{irs} = \frac{\sigma_i - 1}{\sigma_i}\frac{p^o_{irs}o_{irs}}{tp_{ir}p^{ib}_i ta_{irs}} + \frac{\sigma_i - 1}{\sigma_i}\frac{p^o_{irs}o_{irs}}{tp_{ir}p^{ib}_{ir}ta_{irs}}\left(\frac{1}{te_{irs}tp_{ir}b_{ir} + \frac{p^{ts}_{irs}}{p^{ib}_{ir}a^{ts}_{irs}}} - 1\right) \tag{C.9}$$

We can now combine equations (C.7)-(C.9) to solve for N_{ir}:

$$N_{ir} = \frac{\widetilde{q^{ib}_{ir}}}{\sigma_i a_{ir}} \tag{C.10}$$

We can now rewrite equation (C.3) as follows, using the expressions for p^o_{irs} and N_{ir} in (C.6) and (C.10):

$$\frac{t_{irs}ta_{irs}p^{cif}_{irs}}{c^m_{ir}e^m_{is}} = M_{is}^{\frac{\nu_i-1}{1-\sigma_i}}\left(\frac{\widetilde{q^{ib}_{ir}}}{\sigma_i a_{ir}}\right)^{\frac{1}{1-\sigma_i}}\frac{\sigma_i}{\sigma_i - 1}ta_{irs}\tau_{irs}p^{cif}_{irs} \tag{C.11}$$

Equation (C.11) implies the expressions for t_{irs}, c^m_{ir}, and e^m_{is} in the main text.

Appendix C.2 Melitz Economy

The preferences defined in (8) imply the following expression for revenues of a firm with productivity φ:

$$r_{irs}(\varphi) = (M_{is})^{\nu_i-1}\left(\frac{p^o_{irs}(\varphi)}{p^{so}_{is}}\right)^{1-\sigma_i}\sum_{ag}\left(\frac{ta^{so,ag}_{is}p^{so}_{is}}{p^{ag}_{is}}\right)^{1-\rho_i}E^{ag}_{is} \tag{C.12}$$

A standard markup pricing rule follows from profit maximization:

$$p^o_{irs}(\varphi) = \frac{\sigma_i}{\sigma_i - 1}\frac{ta_{irs}\tau_{irs}p^{cif}_{irs}}{\varphi} \tag{C.13}$$

Profits for sales from country r to s can be written as:

$$\pi_{irs}(\varphi) = M_{is}^{\nu_i-1}\left(\frac{p^o_{irs}(\varphi)}{p^{so}_{is}}\right)^{1-\sigma_i}\sum_{ag}\left(\frac{ta^{so,ag}_{is}p^{so}_{is}}{p^{ag}_{is}}\right)^{1-\rho_i}\frac{E^{ag}_{is}}{ta^{so,ag}_{is}ta_{irs}\sigma} - f_{irs}tp_{ir}p^{ib}_{ir} \tag{C.14}$$

We can now define a zero cutoff profit (ZCP) and free entry (FE) condition. The ZCP dictates that a firm with a cutoff productivity level, φ^*_{irs}, makes zero profit ex post (so knowing its productivity and having already paid sunk entry costs). Substituting the pricing equation (C.13) into the expression for profit in (C.14) and solving for φ^*_{irs} leads to:

$$\varphi^*_{irs} = \frac{\frac{\sigma_i}{\sigma_i-1}ta_{irs}\tau_{irs}p^{cif}_{irs}}{\left(\sigma_i f_{irs}p^{ib}_{ir}ta_{irs}\right)^{\frac{1}{1-\sigma_i}}}\left(\sum_{ag}M_{is}^{\nu_i-1}\left(\frac{ta^{so,ag}_{is}p^{so}_{is}}{P^{ag}_{is}}\right)^{1-\rho_i}\frac{M_j^{\nu-1}\left(p^{so}_{is}\right)^{\sigma_i-1}E^{ag}_{is}}{ta^{so,ag}_{is}}\right)^{\frac{1}{1-\sigma_i}} \tag{C.15}$$

According to the free entry condition, expected profit before entry (ex ante) is equal to the sunk entry costs:

$$\sum_{s=1}^{S}\left(1 - G_{ir}\left(\varphi^*_{irs}\right)\right)\pi_{irs}\left(\widetilde{\varphi}_{irs}\right) = \delta en_{ir}tp_{ir}p^{ib}_{ir} \tag{C.16}$$

$\widetilde{\varphi}_{irs}$ is average productivity defined as:

$$\widetilde{\varphi}_{irs} = \left(\int_{\varphi^*_{irs}}^{\infty}\varphi^{\sigma-1}\frac{g_{ir}(\varphi)}{1 - G_{ir}\left(\varphi^*_{irs}\right)}d\varphi\right)^{\frac{1}{\sigma_i-1}} = \left(\frac{\theta_i}{\theta_i - \sigma_i + 1}\right)^{\frac{1}{\sigma_i-1}}\varphi^*_{irs} \tag{C.17}$$

The second equality follows from imposing a Pareto distribution for productivity φ, as in equation (12).

Imposing the ZCP and $\frac{r_{irs}(\varphi_1)}{r_{irs}(\varphi_2)} = \left(\frac{\varphi_1}{\varphi_2}\right)^{\sigma_i - 1}$, the FE can be expressed as:

$$\sum_{s=1}^{S} \left(1 - G_{ir}\left(\varphi^*_{irs}\right)\right) tp_{ir} p^{ib}_{ir} f_{irs} \left(\left(\frac{\widetilde{\varphi}_{irs}}{\varphi^*_{irs}}\right)^{\sigma_i - 1} - 1\right) = \delta en_{ir} tp_{ir} p^{ib}_{ir} \tag{C.18}$$

Finally, we can rewrite the FE imposing the Pareto distribution and employing equation (C.17):

$$\sum_{s=1}^{S} \left(\frac{\kappa_{ir}}{\varphi^*_{irs}}\right)^{\theta} f_{irs} \frac{\sigma_i - 1}{\theta_i - \sigma_i + 1} = \delta en_{ir} \tag{C.19}$$

Before defining the bilateral price in the Melitz model, we still need to derive an expression for the number of varieties, N_{irs}. With a steady state of entry and exit, the number of entrants, NE_{ir}, times the probability of successful entry, $1 - G_{ir}\left(\varphi^*_{irs}\right)$, is equal to the number of exiting firms, δN_{irs}:

$$N_{irs} = \frac{\left(1 - G_{ir}\left(\varphi^*_{irs}\right)\right) NE_{ir}}{\delta} = \left(\frac{\kappa_{ir}}{\varphi^*_{irs}}\right)^{\theta_i} \frac{NE_{ir}}{\delta} \tag{C.20}$$

Combining the free entry condition with factor market equilibrium, enables us to write the number entrants, NE_{ir}, as a function of the number of factor input bundles, q^{ib}_{ir}:

$$NE_{ir} = \frac{\sigma_i - 1}{\theta_i \sigma_i} \frac{\widetilde{q^{ib}_{ir}}}{en_{ir}} \tag{C.21}$$

We have now expressions for all the components featuring in the bilateral price, defined in equation (C.1) and rewritten as follows:

$$\frac{p_{irs}}{e^m_{is}} = \frac{t_{irs} ta_{irs} p^{cif}_{irs}}{c^m_{ir} e^m_{is}} = M_{is}^{\frac{\nu_i - 1}{1 - \sigma_i}} N_{irs}^{\frac{1}{1 - \sigma_i}} p_{irs}\left(\widetilde{\varphi}_{irs}\right)$$

So, using the expression for N_{irs} in (C.20), for NE_{ir} in (C.21), for $p_{irs}(\varphi)$ in (C.13), and for $\widetilde{\varphi}_{irs}$ in (C.17), we can write:

$$\frac{p_{irs}}{e^m_{is}} = \frac{t_{irs} ta_{irs} p^{cif}_{irs}}{c^m_{ir} e^m_{is}} = M_{is}^{\frac{\nu_i - 1}{1 - \sigma_i}} \left(\frac{\kappa_{ir}}{\varphi^*_{irs}}\right)^{\frac{\theta_i}{1 - \sigma_i}} \left(\frac{\sigma_i - 1}{\theta_i \sigma_i} \frac{\widetilde{q^{ib}_{ir}}}{\delta en_{ir}}\right)^{\frac{1}{1 - \sigma_i}} \frac{\sigma_i}{\sigma_i - 1} \frac{ta_{irs} \tau_{irs} p^{cif}_{irs}}{\left(\frac{\theta_i}{\theta_i - \sigma_i + 1}\right)^{\frac{1}{\sigma_i - 1}} \varphi^*_{irs}} \tag{C.22}$$

Rearranging and substituting for φ^*_{irs} from (C.15) gives after straightforward reorganizing the following final expression for international flows:

$$\begin{aligned} \frac{p_{irs}}{e^{so}_{is}} = {} & \gamma_{m,i} \left(\frac{\kappa^{\theta_i}_{ir} \widetilde{q^{ib}_{ir}}}{\delta en_{ir}}\right)^{\frac{1}{1 - \sigma_i}} \left(p^{cif}_{irs}\right)^{\frac{\theta_i}{\sigma_i - 1}} \left(f_{ir} tp_{ir} p^{ib}_{ir}\right)^{\frac{\theta + \sigma - 1}{(\sigma - 1)^2}} ta_{irs}^{\frac{\theta_i}{\sigma_i - 1} + \frac{\theta_i - \sigma_i + 1}{(\sigma_i - 1)^2}} \left(\tau_{irs}\right)^{\frac{\theta_i}{\sigma_i - 1}} \\ & * M_{is}^{\frac{\nu_i - 1}{1 - \sigma_i}} \left(\sum_{ag} M_{is}^{\nu_i - 1} \left(\frac{p^{ag}_{is}}{ta^{m,ag}_{is} p^m_{is}}\right)^{\rho - 1} \frac{\left(p^m_{is}\right)^{\sigma - 1} E^{ag}_{is}}{ta^{m,ag}_{is}}\right)^{-\frac{\theta_i - \sigma_i + 1}{(\sigma_i - 1)^2}} \end{aligned} \tag{C.23}$$

And for domestic flows we get:

$$\begin{aligned} \frac{p^{d,ag}_{iss}}{e^d_{is}} = \frac{tp_{is} p^{ib}_{is}}{e^d_{is} c^d_{is}} = {} & \gamma_{m,i} \left(\frac{\kappa^{\theta_i}_{is} \widetilde{q^{ib}_{is}}}{\delta en_{is}}\right)^{\frac{1}{1 - \sigma_i}} \left(tp_{is} p^{ib}_{is}\right)^{\frac{\theta_i}{\sigma_i - 1} + \frac{\theta_i + \sigma_i - 1}{(\sigma_i - 1)^2}} \\ & * M_{is}^{\frac{\nu_i - 1}{1 - \sigma_i}} \left(\sum_{ag} M_{is}^{\nu_i - 1} \left(\frac{p^{ag}_{is}}{ta^{m,ag}_{is} p^m_{is}}\right)^{\rho - 1} \frac{\left(p^m_{is}\right)^{\sigma - 1} E^{ag}_{is}}{ta^{m,ag}_{is}}\right)^{-\frac{\theta_i - \sigma_i + 1}{(\sigma_i - 1)^2}} \end{aligned} \tag{C.24}$$

The expressions for e_{is}^{so}, t_{irs}, and c_{ir}^{so} in the main text follow from equations (C.23)-(C.24). Comparing these two equations shows why the coefficients on $tp_{ir}p_{ir}^{ib}$ are different for imported and domestic flows: the impact through marginal costs in production runs through p_{irs}^{cif} for international flows.

Appendix D Additional Tables

Table D1: Overview of regions, sectors, and production factors

Regions	Description	Sectors	Description	Production factors	
EAA	East Asia	Agriculture	Primary Agriculture	Land	Land
SEA	Southeast Asia	Extraction	Mining and Extraction	lowskill	Low-skilled
SOA	South Asia	ProcFood	Processed Food	medskill	Medium-skilled
USA	USA	OtherGoods	Other Goods	highskill	High-skilled
NAmerica	Canada and Mexico	Chemicals	Chemicals; Petrochemicals	capital	Capital
LatinAmer	Latin America	Machinery	Light Manufacturing	natres	Natural resources
efta	EFTA	Metals	Heavy Manufacturing		
EU	European Union 27	Motorvehicle	Motorvehicles		
MENA	Middle East and North Africa	PubServices	Public Services		
SSAROW	Sub-Saharan Africa and ROW	TransComm	Transport and Communication		
REE	Rest of Eastern Europe	OthServices	Other Services		