The Costs and Benefits of Leaving the EU: Trade Effects

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Abstract

What would be the economic consequences of leaving the European Union for living standards in the UK? We estimate the welfare effects of changes in trade and fiscal transfers following Brexit. We use a standard quantitative general equilibrium trade model with multiple sectors, countries and intermediates, as in Costinot and Rodriguez-Clare (2013). Static losses range between 1.28% and 2.61%, depending on the assumptions used in our counterfactual scenarios. The finding that Brexit reduces UK living standards is robust to a wide range of alternative assumptions about what follows Brexit. A more reduced form approach that includes dynamic effects would triple such losses to between 6.3% and 9.5%.

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1 Introduction

In January 2013 Britain's Prime Minister David Cameron committed to holding a referendum on EU membership which will now take place on June 23rd 2016. Supporters of "Brexit" focus on the democratic benefits of repatriating powers back from Brussels. Supporters of the EU argue that the EU reduces the risk of conflict and makes Britain stronger on the world stage. These are important issues, but this technical report focuses purely on the economic costs and benefits, in particular from changes in trade.

Eurosceptics (Morris, 2013) believe that trade with EU countries would not be much affected by an exit because UK's trade deficit with the EU provides enough bargaining power to allow the negotiation of a free trade agreement between the two parties, similar to that enjoyed by Norway or Switzerland. Secondly, Britain would be able to expand its trade with non-EU countries through the negotiations of new trade agreements that would not be subjected to constraints imposed by other EU members. Thirdly, the UK country would be free from the regulatory burden and the costs associated with the EU membership.

Europhiles (Springford and Tilford, 2014) argue that it is unrealistic to expect the same trade terms as smaller countries like Norway or Switzerland, that the UK's ability to strike trade deals with other countries will be weakened, not strengthened outside the EU and that the costs of regulation solely due to the EU are vastly exaggerated. Furthermore, there are many other aspects that need to be taken into consideration (Harari and Thompson, 2013).

In this paper we focus on the welfare gains arising from trade openness with EU countries to quantify some of the effects associated with an eventual withdrawal from the EU. Our methodology is based on Costinot and Rodriguez-Clare (2013). We set up a general equilibrium trade model which covers 31 sectors and aggregates the world into 35 regions. We define distinct scenarios after Brexit and calculate the changes in welfare as measured in real consumption. The welfare loss from Brexit is obtained by comparing the welfare one in which UK remains to be an EU member and one in which the UK does not. We find that increases in bilateral tariffs and non-tariff barriers between the UK and the EU and exclusion of the UK from future integration of the EU lead to a drop in UK welfare even after accounting for lower fiscal transfers to the EU. The welfare changes range from -1.28% in an optimistic scenario, to -2.61% in a pessimistic one. We carry out various checks to test the robustness of our results.

The welfare loss is not limited to the UK. EU countries that trade intensively with the UK tend to lose more. For example, Ireland suffers the largest losses from Brexit. For countries outside the EU, they tend to have a small welfare gain, mostly due to a trade diversion effect. As a whole, however, the world beyond the UK's shores is poorer after Brexit.

In our basic setup, trade liberalization tends to increase welfare due to the specialization of countries in their areas of comparative advantage [1] and the availability of cheaper goods and services and/or cheaper inputs (Eaton and Kortum, 2002). Our baseline calculations, however, leave out many factors that could lead to further losses following an exit from the EU. For example, the reduction in the variety of goods and services available for consumption (Krugman, 1980) and the fall in productivity due to weaker competition from abroad (Melitz, 2003), and the presence of vertical production chains in the UK (Melitz and Redding, 2014) will most likely increase such losses. Furthermore, contrary to popular belief, ceasing migration flows between UK and other EU countries, one of the EU most basic principles, will also tend to decrease welfare not only in the source region but also in the destination one (di Giovanni, Levchenko, and Ortega, 2015).

Our main analysis is also static in nature and gains from trade can be considerably larger when we factor in dynamic effects. Trade openness can increase growth rates due to a rise in investment in capital (Wacziarg, 1998), increases in technology diffusion (Sampson, 2016; Wacziarg, 1998), export learning effects (Albornoz, Calvo Pardo, Corcos, and Ornelas, 2012; Egger, Larch, Staub, and Winkelmann, 2011) and greater investment in R&D (Bloom, Draca, and Van Reenen, 2015; Keller, 1999, 2002).

An alternative way to evaluate the impact of Brexit and take into account *part* of these dynamic effects is to use the results of simple, less theory-based empirical studies of the effects of EU membership. Baier, Bergstrand, Egger, and McLaughlin (2008) find that, after controlling for other determinants of bilateral trade, EU members trade substantially more with other EU countries than they do with members of the European Free Trade Association (EFTA). Their estimates imply that, if the UK leaves the EU and joins EFTA, its trade with countries in the EU will fall by about a quarter. Combining this with the estimates from Feyrer (2009) implies that leaving the EU (and joining EFTA) will reduce UK income by between 6.3% and 9.5%. These estimates are much higher than the costs obtained from the static analysis, implying that dynamic effects from trade are important.

The structure of the paper is as follows. We lay out the conceptual framework which captures the welfare effect of Brexit in section 2. Then we present the data and our counterfactual analysis

[1] More technically, an expansion in the set of feasible allocations leads to Pareto superior outcomes.

in Section 3. In Section 4 we do various robustness check of our empirical results. Section 5 uses alternative non-structural approaches to calculate welfare losses. We offer concluding comments in Section 6.

2 Conceptual Framework

Formally, to quantify the trade-related welfare effects of Brexit we rely on structural estimation based on a quantitative trade models whose calibration and simulation have been increasingly used to investigate *ex ante* the implications of trade policies in counterfactual scenarios for which data are necessarily unavailable.[2]

In particular, we build on (Arkolakis, Costinot, and Rodriguez-Clare, 2012) and (Costinot and Rodriguez-Clare, 2013), who show that some of the most popular models used by trade economists fall in a specific class share the same predicted 'gains from trade' (defined as welfare with trade relative to welfare with autarky), conditional on the changes in two aggregate statistics: the observed share of domestic expenditure and an estimate of the trade elasticity.[3]

We use some simple relationships from this class of models to calculate what happens to income (and therefore consumption and welfare) when trade costs change. Essentially, we use information we know on current trade patterns and feed in different counterfactual scenarios about changes in trade costs after Brexit. Taking the estimates of the trade elasticity from the literature we can then figures out how trade patterns and income will change, depending on the degree to which trade costs rise.

These models have four primitive assumptions in common: (a) Dixit-Stiglitz preferences; (b) one factor of production; (c) linear cost functions; (d) perfect or monopolistic competition. They also share three common macro-level restrictions: (A) trade is balanced; (B) aggregate profits are a constant share of aggregate revenues; (C) the import demand system exhibits constant elasticity of substitution (CES). As this set of assumptions is extremely restrictive, one would be forgiven for - thinking they have limited practical relevance. What makes, instead, those restrictive assumptions relevant is that some of the most popular trade models do satisfy them, from the workhorse CGE model by (Armington, 1969) to the hallmark 'new trade theory' model by (Krugman, 1980), to the Ricardian model by (Eaton and Kortum, 2002) and several variations of the heterogeneous model

[2]This section is based on (Ottaviano, 2014).

[3]See (Head and Mayer, 2014) as well as (Simonovska and Waugh, 2014) for recent discussions of methodological issues related to the estimation of the trade elasticity.

by (Melitz, 2003).

The idea of using mathematical or statistical models to simulate the effects of counterfactual scenarios has a long tradition (Baldwin and Venables, 1995). In particular, 'Computable general equilibrium' (CGE) models remain a cornerstone of trade policy evaluation (Piermartini and Teh, 2005), having also contributed to the design of advanced softwares for their numerical solution such as GAMS or GEMPACK. To this tradition the class of models we rely on contribute a tighter connection between theory and data thanks to more appealing micro-theoretical foundations and careful estimation of the structural parameters necessary for counterfactual analysis (Costinot and Rodriguez-Clare, 2013).

We first explain the basic logic of this approach to calibration and simulation through a simplified model. We then describe the elements of the model we actually use.

2.1 The Armington Model

Following (Costinot and Rodriguez-Clare, 2013), the basic logic of our approach can be usefully illustrated through a simple Armington model. The economy consists of n countries, indexed $i = 1, ..., n$, with each country supplying its own distinct good. There are thus n goods, also indexed $i = 1, ..., n$, with country i being the only supplier of good i in fixed quantity Q_i, which corresponds to the country's endowment of the good.

Preferences in country j are captured by a representative household with Dixit-Stiglitz utility function:

$$C_j = \left[\sum_{i=1}^{n} \left(\frac{C_{ij}}{\psi_{ij}} \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \tag{1}$$

where C_{ij} is country j's consumption of the good supplied by country i, $\psi_{ij} > 0$ is an inverse measure of the appeal of this good for country j, and $\sigma > 1$ is the constant elasticity of substitution (CES) between goods supplied by different countries. According to (1), utility can be interpreted as the level of consumption of an aggregate composite ('quantity index') of the various goods whose 'price index' is

$$P_j = \left[\sum_{i=1}^{n} (\psi_{ij} P_{ij})^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \tag{2}$$

where P_{ij} is the price of good i in country j. Denoting aggregate expenditure by E_j, the price and quantity indices satisfy $P_j C_j = \sum_{i=1}^{n} P_{ij} C_{ij} = E_j$, which is the representative household's budget constraint. Utility (1) can then be equivalently rewritten as

$$C_j = \frac{E_j}{P_j} \tag{3}$$

which identifies *real expenditure* as a measure of country j's welfare.

External trade between countries is subject to trade costs, consisting of frictional and tariff barriers. Frictions are of the *iceberg* type: country i has to ship $\tau_{ij} \geq 1$ units of its good for one unit to reach country j. Tariff barriers are of the *ad-valorem* type with $t_{ij} \geq 0$ denoting the tariff imposed by country j on imports from country i. There are, instead, no trade costs for internal trade: $\tau_{jj} = \tau'_{jj} = 1$ and $t_{jj} = t'_{jj} = 0$.

Markets are perfectly competitive and perfect arbitrage implies that the price of a good at destination equals its price at the origin once trade costs are taken into account: $P_{ij} = (1 + t_{ij})\, \tau_{ij} P_{ii}$. This in turn implies that a country's income equals the country's good endowment times its domestic price: $Y_i = P_{ii} Q_i$. Hence, the price at destination satisfies

$$P_{ij} = \frac{\phi_{ij} Y_i}{Q_i} \tag{4}$$

where $\phi_{ij} \equiv (1 + t_{ij})\tau_{ij}$ denotes the trade costs from country i to country j.

Given (1), utility maximization under the representative household's budget constraint determines the value of country j's imports from country i inclusive of the associated tariff revenue

$$X_{ij} = \left(\frac{\psi_{ij} P_{ij}}{P_j} \right)^{1-\sigma} E_j \tag{5}$$

with $E_j = \sum_{i=1}^{n} X_{ij}$. By (2) and (5), the share of expenditure of country j on imports from country i evaluates to

$$\lambda_{ij} = \frac{X_{ij}}{E_j} = \left(\frac{\psi_{ij} P_{ij}}{P_j} \right)^{1-\sigma} = \frac{(\phi_{ij} Y_i)^{-\varepsilon} (Q_i / \psi_{ij})^{\varepsilon}}{\sum_{i=1}^{n} (\phi_{ij} Y_i)^{-\varepsilon} (Q_i / \psi_{ij})^{\varepsilon}} \tag{6}$$

where $\varepsilon \equiv \partial \ln (X_{ij} / X_{jj}) / \partial \ln \tau_{ij} = \sigma - 1$ denotes the 'trade elasticity': the elasticity of imports relative to domestic demand X_{ij}/X_{jj} with respect to bilateral trade costs ϕ_{ij} holding income levels constant. Given (6), equation (5) can be then restated as a standard 'gravity equation'

$$X_{ij} = \lambda_{ij} E_j = \frac{(\phi_{ij} Y_i)^{-\varepsilon} (Q_i / \psi_{ij})^{\varepsilon}}{\sum_{i=1}^{n} (\phi_{ij} Y_i)^{-\varepsilon} (Q_i / \psi_{ij})^{\varepsilon}} E_j \tag{7}$$

which expresses the bilateral trade flow from i to j as a function of characteristics of the country of origin (Y_i and Q_i), characteristics of the country of destination (E_j), and bilateral obstacles (ϕ_{ij} and ψ_{ij}).

In equilibrium expenditure equals income plus tariff revenue

$$E_j = Y_j + T_j \tag{8}$$

with

$$T_j = \sum_{i=1}^{n} \frac{t_{ij}}{1+t_{ij}} X_{ij} \tag{9}$$

and

$$Y_i = \sum_{j=1}^{n} \frac{1}{1+t_{ij}} X_{ij} \tag{10}$$

where $X_{ij}/(1+t_{ij})$ is the tax base. By (6) the share of tariff revenue in country j's expenditure can be expressed as

$$\pi_j = \frac{T_j}{E_j} = \sum_{i=1}^{n} \frac{t_{ij}}{1+t_{ij}} \lambda_{ij} \tag{11}$$

which allows one to use (8) to state country j's total expenditure as a function of its income

$$E_j = \frac{Y_j}{1-\pi_j} \tag{12}$$

Plugged together with (7) into (10), (12) implies that good i's market clears as long as

$$Y_i = \sum_{j=1}^{n} \frac{1}{1+t_{ij}} \frac{(\phi_{ij} Y_i)^{-\varepsilon} (Q_i/\psi_{ij})^{\varepsilon}}{\sum_{i=1}^{n} (\phi_{ij} Y_i)^{-\varepsilon} (Q_i/\psi_{ij})^{\varepsilon}} \frac{Y_j}{1-\pi_j} \tag{13}$$

holds. After using (11) and (6) to substitute π_j with an expression in which income levels are the only endogenous variables, for $i = 1, ..., n$ (13) generates a system of n equations in n unknowns that can be solved for the equilibrium income levels $Y = \{Y_i\}$. However, as by Walras' Law, one of those equations is redundant, income levels can be determined only up to a constant pinned down by the choice of the numeraire good. Having determined the equilibrium income levels, the corresponding bilateral prices and price indices $P = \{P_{ij}\}$ can be recovered from (4) and (2) respectively. With the price information at hand, trade flows $X = \{X_{ij}\}$ and expenditures $E = \{E_i\}$ can then be obtained from (5) and $E_j = \sum_{i=1}^{n} X_{ij}$. This provides also information required to compute expenditure shares $\lambda = \{\lambda_{ij}\}$ from (6) and tax revenue shares $\pi = \{\pi_i\}$ from (11). Finally, knowing prices and expenditures, welfare $C = \{C_i\}$ can be measured from (3). This concludes the description of the model and its equilibrium solution.

2.2 Welfare Effects of Changes in Trade Costs

How do changes in trade costs affect national welfare? To answer this question one has to assess what happens to C when trade costs change from actual levels $\phi = \{\phi_{ij}\}$ to counterfactual levels $\phi' = \left\{\phi'_{ij}\right\}$. The main insights of Arkolakis, Costinot and Rodriguez-Clare (2012) is that changes in the real expenditure of a country j can be readily computed using only few statistics: the trade elasticity (ε) and the changes in the country's shares of expenditure across goods (from $\lambda = \{\lambda_{ij}\}$ to $\lambda' = \left\{\lambda'_{ij}\right\}$).

To see this, one needs first to derive three preliminary results on the effects of an infinitesimal change in trade costs. First, given (2), partially differentiating P_j with respect to P_{ij} yields

$$\frac{\partial P_j}{\partial P_{ij}} = \left[\sum_{i=1}^{n} (\psi_{ij} P_{ij})^{1-\sigma}\right]^{\frac{\sigma}{1-\sigma}} (\psi_{ij})^{1-\sigma} (P_{ij})^{-\sigma} = \left(\frac{\psi_{ij} P_{ij}}{P_j}\right)^{1-\sigma} \frac{P_j}{P_{ij}}$$

which, by (5), can be rewritten as

$$\frac{\partial P_j}{\partial P_{ij}} = \frac{X_{ij}}{E_j} \frac{P_j}{P_{ij}}$$

implying the total differential

$$d \ln P_j = \sum_{i=0}^{n} \lambda_{ij} d \ln P_{ij} \tag{14}$$

This change in country j's price index can be further broken down into changes of domestic and import prices as

$$d \ln P_j = \lambda_{jj} d \ln P_{jj} + (1 - \lambda_{jj})\, d \ln P_j^M \tag{15}$$

where

$$P_j^M = \left[\sum_{i \neq j} (\psi_{ij} P_{ij})^{1-\sigma}\right]^{\frac{1}{1-\sigma}}$$

is the component of P_j associated with imports, and

$$d \ln P_j^M = \frac{1}{1 - \lambda_{jj}} \sum_{i \neq j} \lambda_{ij} d \ln P_{ij}$$

is its variation. Second, (6) and (5) imply

$$\frac{\lambda_{jj}}{1-\lambda_{jj}} = \left(\frac{\psi_{jj} P_{jj}}{\psi_{ij} P_j^M}\right)^{1-\sigma} = \left(\frac{\psi_{jj}}{\psi_{ij}}\right)^{1-\sigma} \left(\frac{P_{jj}}{P_j^M}\right)^{1-\sigma}$$

which can be totally differentiated to obtain

$$d\ln P_j^M = d\ln P_{jj} + \frac{1}{1-\sigma}\left[d\ln\left(1-\lambda_{jj}\right) - d\ln\lambda_{jj}\right] \tag{16}$$

Third, the fact that expenditure shares sum up to one requires

$$\lambda_{jj} + (1-\lambda_{jj}) = 1$$

the total differentiation of which leads to

$$(1-\lambda_{jj})\, d\ln(1-\lambda_{jj}) = -\lambda_{jj} d\ln\lambda_{jj} \tag{17}$$

Then, plugging (16) and (17) into (15) gives

$$d\ln P_j = d\ln P_{jj} - \frac{1}{1-\sigma} d\ln\lambda_{jj} \tag{18}$$

so that the change in country j's real expenditure $C_j = E_j/P_j$ can be written as

$$d\ln C_j = d\ln E_j - d\ln P_j = d\ln E_j - d\ln P_{jj} - \frac{1}{1-\sigma} d\ln\lambda_{jj} \tag{19}$$

This expression can be further simplified recalling that there are no internal trade costs ($\tau_{jj} = \tau'_{jj} = 1$ and $t_{jj} = t'_{jj} = 0$) and trade must balance ($Y_j = (1-\pi_j)E_j$). Under these conditions, (4) implies $P_{jj}Q_j = Y_j = (1-\pi_j)E_j$ and thus $d\ln E_j - d\ln P_{jj} = -d\ln(1-\pi_j)$ since Q_j is a fixed endowment. Given $\varepsilon = \sigma - 1$, (19) finally becomes

$$d\ln C_j = -d\ln(1-\pi_j) - \frac{1}{\varepsilon} d\ln\lambda_{jj} \tag{20}$$

which shows that the welfare change $d\ln C_j$ is driven by the changes in the expenditure share of tariff revenue π_j and in the expenditure share on the domestic good λ_{jj}.

Expression (20) holds only for infinitesimal changes in trade costs, which tend to be of little practical relevance. Nevertheless, it can be readily integrated to characterize the welfare effects of discrete changes. This yields

$$\widehat{C}_j = \frac{1-\pi_j}{1-\pi_j'} \left(\widehat{\lambda}_{jj}\right)^{-\frac{1}{\varepsilon}} \tag{21}$$

where the share of tariff revenues in the actual and counterfactual equilibria are given by

$$\pi_j = \sum_{i=1}^{n} \frac{t_{ij}}{1+t_{ij}} \lambda_{ij} \text{ and } \pi_j' = \sum_{i=1}^{n} \frac{t_{ij}'}{1+t_{ij}'} \lambda_{ij} \widehat{\lambda}_{ij}$$

Hence, the welfare consequences of any arbitrary change in trade costs can indeed be computed based only on few sufficient statistics: the trade elasticity and the change in the shares of expenditure across goods.

However, knowing that only few sufficient statistics are needed to compute the welfare effects of trade integration would be of little use unless we had a consistent way of identifying the values of those statistics in the counterfactual scenario. This is clearly not much of a problem for the trade elasticity ε, which, given utility (1), is constant by assumption. It may look more of a problem for the counterfactual expenditure shares $\lambda' = \left\{\lambda_{ij}'\right\}$. Luckily the structure of the model lends a hand.

Consider (6). As ψ_{ij} is constant, taking log changes gives

$$d \ln \lambda_{ij} = d \ln \left(P_{ij}\right)^{1-\sigma} - d \ln \left(P_j\right)^{1-\sigma}$$

which, by (14), can be rewritten as

$$d \ln \lambda_{ij} = d \ln \left(P_{ij}\right)^{1-\sigma} - \sum_{i=0}^{n} \lambda_{ij} d \ln \left(P_{ij}\right)^{1-\sigma} \tag{22}$$

As Q_i is also constant, (4) implies

$$d \ln \left(P_{ij}\right)^{1-\sigma} = d \ln \left(\phi_{ij} Y_i\right)^{1-\sigma}$$

which allows one to restate (22) as

$$d \ln \lambda_{ij} = d \ln \left(\phi_{ij} Y_i\right)^{1-\sigma} - \sum_{i=0}^{n} \lambda_{ij} d \ln \left(\phi_{ij} Y_i\right)^{1-\sigma}$$

for infinitesimal changes, or, by integration, as

$$\widehat{\lambda}_{ij} = \frac{\left(\widehat{\phi}_{ij}\widehat{Y}_i\right)^{-\varepsilon}}{\sum_{l=0}^{n}\lambda_{lj}\left(\widehat{\phi}_{ij}\widehat{Y}_l\right)^{-\varepsilon}} \tag{23}$$

for discrete changes given $\varepsilon = \sigma - 1$.

In the counterfactual equilibrium, (6), (12) and (10) further imply

$$Y'_j = \sum_{i=1}^{n} \frac{1}{1+t'_{ij}} \lambda'_{ij} \frac{Y'_i}{1-\pi'_i}$$

which can be rewritten as

$$\widehat{Y}_j Y_j = \sum_{i=1}^{n} \frac{1}{1+t'_{ij}} \widehat{\lambda}_{ij}\lambda_{ij}\widehat{Y}_i \frac{Y_i}{1-\pi'_i}$$

so that using (23) to substitute for $\widehat{\lambda}_{ij}$ yields

$$\widehat{Y}_j Y_j = \sum_{i=1}^{n} \frac{1}{1+t'_{ij}} \frac{\lambda_{ij}\left(\widehat{\phi}_{ij}\widehat{Y}_i\right)^{-\varepsilon}}{\sum_{l=0}^{n}\lambda_{lj}\left(\widehat{\phi}_{lj}\widehat{Y}_l\right)^{-\varepsilon}} \frac{\widehat{Y}_i Y_i}{1-\pi'_i} \tag{24}$$

The share of tariff revenues in the counterfactual equilibrium is itself given by

$$\pi'_i = \sum_{i=1}^{n} \frac{t'_{ij}}{1+t'_{ij}} \lambda'_{ij} = \sum_{i=1}^{n} \frac{t'_{ij}}{1+t'_{ij}} \widehat{\lambda}_{ij}\lambda_{ij}$$

which, by (23), becomes

$$\pi'_i = \sum_{i=1}^{n} \frac{t'_{ij}}{1+t'_{ij}} \frac{\lambda_{ij}\left(\widehat{\phi}_{ij}\widehat{Y}_i\right)^{-\varepsilon}}{\sum_{l=0}^{n}\lambda_{lj}\left(\widehat{\phi}_{ij}\widehat{Y}_l\right)^{-\varepsilon}} \tag{25}$$

After using (25) to substitute for π'_i, (24) generates a system of n equations in n unknown income changes that can be solved for the counterfactual $\widehat{Y} = \left\{\widehat{Y}_i\right\}$ (up to a normalization due the choice of the numeraire good). As the system does not depend directly on the utility parameters $\psi = \{\psi_{ij}\}$ and the endowments $Q = \{Q_i\}$, changes in factor income levels $\widehat{Y} = \left\{\widehat{Y}_i\right\}$ can be determined using only the initial expenditure shares $\lambda = \{\lambda_{ij}\}$, the initial income levels $Y = \{Y_i\}$, and the trade elasticity ε. Once the changes in income $\widehat{Y}$ have been solved for, the changes in expenditure shares $\widehat{\lambda} = \left\{\widehat{\lambda}_{ij}\right\}$ and the counterfactual tax revenues $\pi' = \{\pi'_i\}$ can be obtained from (23) and (25) respectively. Plugging them into (21) finally determines the welfare change $\widehat{C}_j$ in the counterfactual scenario. Hence, the welfare effects of trade cost changes can be evaluated estimating only the trade elasticity and not all the structural parameters of the model.

2.3 Intuition

Although the structure can appear complex at first sight, it is in fact very simple. Consider (24) as the central relationship we can exploit to figure out the implications of Brexit. For each country we want to measure the income changes $\widehat{Y}$ as trade costs rise after Brexit. We have different scenarios (optimistic or pessimistic) associated with different trade costs changes $\widehat{\phi}_{ij}$. We also have data on the initial income Y and expenditure shares λ of each country, and take an estimate of the trade elasticity ε from the literature. So basically we find the pattern of income changes that are consistent with the new set of bilateral trade costs given the initial level of trade and how sensitive these patterns are to price changes.

Think of this from a single country's perspective. When trade costs rise, revenues from exports fall as other countries buy less exports. To maintain trade balance, imports will also have to fall. Both of these will decrease income (and this will have knock-on effects to other countries even if trade costs have not changed for these countries). In equilibrium trade must balance so all of the trade and income changes must be consistent with each other for every country. This is what (24) describes.

2.4 Brexit and National Welfare

In the case of Brexit, we want to quantify not only the instantaneous welfare effects as done so far but also its cumulative welfare effects in the future. This forward-looking perspective introduces two additional layers of complexity. First of all, we need to evaluate the present value of future utility flows. To do so, we assume that our representative household in country j has an infinite life horizon so that its intertemporal utility can be expressed as

$$U_{j,0} = \sum_{t=0}^{\infty} \beta^t \ln C_{j,t} \tag{26}$$

where real consumption $C_{j,t}$ is defined by (1) after making time dependence explicit and t is a time index starting from the current period $t = 0$.[4] Analogously, in a counterfactual scenario

[4] We follow (Caliendo, Dvorkin, and Parro, 2015) in adopting log-preferences. These imply constant unit elasticity of intertemporal substitution. Alternative assumptions on this elasticity are incompatible with the "exact hat algebra"

intertemporal utility can be expressed as

$$U'_{j,0} = \sum_{t=0}^{\infty} \beta^t \ln C'_{j,t}.$$

The second layer of complexity comes from the fact that the future welfare effects of the UK leaving the EU should be calculated relative not only to today's welfare but also to the evolution of future welfare if the UK stays in the EU. This implies that we have to compare the present value of future utility between two counterfactuals: if the UK stays in the EU

$$U^{In}_{j,0} = \sum_{t=0}^{\infty} \beta^t \ln C^{In}_{j,t}$$

and if the UK leaves

$$U^{Out}_{j,0} = \sum_{t=0}^{\infty} \beta^t \ln C^{Out}_{j,t}.$$

Following (Sampson, 2016), we can then measure the welfare effects of Brexit by using the consumption adjustment that makes the representative household indifferent between staying or leaving the EU over its entire life span. This is measured by the value of the parameter δ_t such that

$$U^{In}_{j,0}(\delta_j) = \sum_{t=0}^{\infty} \beta^t \left(\ln \delta_j + \ln C^{In}_{j,t}\right) = \sum_{t=0}^{\infty} \beta^t \ln C^{Out}_{j,t} = U^{Out}_{j,0}$$

Solving this equation for $\ln \delta_j$ gives the *Brexit consumption equivalent change* for country j

$$\ln \delta^{Brexit}_j = (1-\beta) \sum_{t=0}^{\infty} \beta^t \left(\ln C^{Out}_{j,t} - \ln C^{In}_{j,t}\right) \tag{27}$$

Accordingly, the welfare effects of Brexit can be quantified by evaluating (27). Note that, after defining

$$\ln \delta^{In}_j = (1-\beta) \sum_{t=0}^{\infty} \beta^t \ln \widehat{C}^{In}_{j,t}$$

and

$$\ln \delta^{Out}_j = (1-\beta) \sum_{t=0}^{\infty} \beta^t \ln \widehat{C}^{Out}_{j,t},$$

we apply throughout in the wake of (Costinot and Rodriguez-Clare, 2013).

expression (27) can be equivalently rewritten as

$$\ln \delta_j^{Brexit} = \ln \delta_j^{Out} - \ln \delta_j^{In} = (1-\beta) \sum_{t=0}^{\infty} \beta^t \left(\ln \widehat{C}_{j,t}^{Out} - \ln \widehat{C}_{j,t}^{In} \right) \tag{28}$$

where $\widehat{C}_{j,t}^{In} = C_{j,t}^{In}/C_{j,t}$ and $\widehat{C}_{j,t}^{Out} = C_{j,t}^{Out}/C_{j,t}$ are the changes in real consumption in period t relative to the status quo in period 0 if the UK stays and if the the UK leaves the EU respectively. The idea is that, if the UK stays, it will enjoy any further fall in trade costs among EU members relative to the status quo. The corresponding welfare effects are captured by the consumption equivalent change δ_j^{In}. On the other hand, if the UK leaves the EU, it will miss not only any further fall in trade costs among EU members but might also face higher trade costs when trading with EU members relative to the status quo. The corresponding welfare effects are captured by δ_j^{Out}.

2.5 Our Model

The Armington model has helped us to explain the basic logic of our approach, and in detail the mechanics of its calibration and simulation procedure. It is, however, too stylized for our purposes. Fortunately, (Costinot and Rodriguez-Clare, 2013) have shown that the gravity equation (7), which is the basis for counterfactual analysis in the Armington model, holds under various assumptions about technology and market structure. In what follows, we make the realistic choice of allowing for multiple sectors and tradable intermediate inputs as well as the conservative choice of focusing on the case of perfect competition as this has been shown to provide a *lower bound* to the welfare effects of changes in trade costs.

Specifically, as in (Costinot and Rodriguez-Clare, 2013), we extend the model to multiple sectors, indexed $s = 1, ..., N$, by assuming that the good consumed by the representative household in (26) is a Cobb-Douglas basket of the goods supplied by the different sectors

$$C_j = \prod\nolimits_{s=1}^{S} C_{j,s}^{\beta_{j,s}}$$

where, leaving time dependence t implicit for ease of notation, $C_{j,s}$ is real consumption of the good supplied by sector s and $\beta_{j,s} \in (0,1)$ is its share of household expenditures with $\sum_{s=0}^{S} \beta_{j,s} = 1$. By analogy with the single sector expression (21), the change in real consumption generated by a counterfactual change in trade costs equals

$$\widehat{C}_j = \frac{1-\pi_j}{1-\pi'_j} \prod_{s=1}^{S} \left(\widehat{\lambda}_{jj,s}\right)^{-\frac{\beta_{j,s}}{\varepsilon_s}} \tag{29}$$

where the π_j and π'_j are again the shares of tariff revenue in country j's expenditure in the current and counterfactual scenarios respectively. Clearly, (29) boils down to (21) when we only have one sector. To add also intermediates, we assume that each sector output is used not only in final consumption but also, together with primary factors, as input for its own and any other sector's production. If we use $\alpha_{j,sk} \in [0,1]$ to denote the share of sector k's output in sector s's expenditure on intermediate inputs, we get

$$\widehat{C}_j = \frac{1-\pi_j}{1-\pi'_j} \prod_{s,k=1}^{S} \left(\widehat{\lambda}_{jj,k}\right)^{-\frac{\beta_{j,s}\widetilde{a}_{j,sk}}{\varepsilon_k}} \tag{30}$$

where $\widetilde{a}_{j,sk}$ is the elasticity of the price index in sector s with respect to changes in the price of sector k. These price elasticities are given by the elements of the $S \times S$ Leontief inverse matrix $(Id - A_j)^{-1}$ where A_j is the matrix with typical element $\alpha_{j,sk}$. Expression (30) is what we use to evaluate $\widehat{C}^{In}_{j,t}$ and $\widehat{C}^{Out}_{j,t}$ for the quantification of the the welfare effects of Brexit through (28).

3 Empirical Analysis

In this section, we specify the time path of changes in the iceberg trade costs and tariffs if the UK remains a member of the EU and if it does not under different scenarios. Then we quantify the effects of such changes in tariff and/or trade costs on welfare and trade using the structural model specified in previous section.

3.1 Data

We use the latest World Input-Output Database (WIOD) for year 2011.[5]. This database aggregates the world into 40 countries and covers 35 sectors which we further aggregate into 35 regions and 31 sectors as in Costinot and Rodriguez-Clare (2013) We also collect information on the applied most favoured nation (MFN) tariff by the EU from the World Trade Organization (WTO) website[6], which provides information on tariffs at the *product* level (HS classification) for all tradable goods.

[5]The data could be found at http://www.wiod.org/new_site/home.htm. For more details on how this database is constructed, see Dietzenbacher, Los, Stehrer, Timmer, and de Vries (2013).

[6]http://tariffdata.wto.org/

We also use the United Nations (UN) Comtrade bilateral database at the product level. These two datasets permit us to calculate an average MFN tariff at the WIOD sector level for UK imports (exports), from (to) the EU by using import (export) value at the product level as weights. [7] The resulting average MFN tariffs for imports and exports from/to the EU can be seen in Table A.3, which summarizes the UK trade and MFN tariff information at the sector level. The table splits the sectors between 'Goods' and 'Services'.

The most intensively traded good in the UK/EU bilateral relationship is 'Transport Equipment', that includes auto-mobiles, amounting to 95.7 billion of US dollars in 2011. This sector also possesses one of the highest average tariffs: 8.09% for imports from the EU and 7.22% for exports to the EU. Note that most part of this trade is composed by imports (60.4 billion, or 63%). On the other hand, the trade champion among services, the sector 'Renting of Machinery and Equip. and Other Business Services', is more intensively exported (USD 53 billions) than imported (USD 28 billion) by the UK. Financial services also are responsible for a significant trade share. Together, the two former sectors are responsible for more than two thirds of the flows of services between the UK and the EU. In general, we can see that the UK holds a deficit among goods and a surplus among services, with reasonable variability within the two groups.

3.2 Counterfactuals

In this section we present counterfactual exercises associated with the UK leaving the EU. We aim to quantify changes in welfare (real UK consumption) coming from three distinct sources: i) immediate changes in goods tariffs, ii) immediate changes in non-tariff barriers, and iii) exclusion from future market integration in the EU.

We consider two different scenarios. In the pessimistic case we assume that the UK is no longer part of the single market and will trade with the EU under the regulations of the WTO. The UK will apply the MFN tariffs seen in column (4) of Table A.3 on goods imported from the EU, while the EU will apply the tariffs observed in column (7) on goods originating from the UK. This seems reasonable just after withdrawal, but the hope is that the UK will eventually be able to negotiate a better deal such as enjoyed by Norway and Iceland (in the European Economic Area) or Switzerland (which has a series of bilateral deals). Hence, in our optimistic scenario we consider that tariffs on goods continue to be zero between the UK and the EU.

Another important source of trade costs around the world is due to non-tariff barriers. Non-

[7] We aggregate HS 6-digit industries into 2-digit WIOD industries using a concordance between HS and ISIC Rev3.

tariff barriers are related to costs of shipment, differences in product regulations, legal barriers, whether countries share a border, a common currency or language, search and other transaction costs for both goods and services, etc (Anderson and van Wincoop, 2004; Head and Mayer, 2013). Many authors point out that such costs are higher than formal tariffs (Anderson and van Wincoop, 2004; Novy, 2013; LooiKee, Nicita, and Olarreaga, 2009). In fact, most part of the negotiations regarding the Transatlantic Trade and Investment Partnership between the EU and the USA aim to diminish non-tariff barriers.

To incorporate non-tariff barriers we use information provided by Berden, Francois, Tamminen, Thelle, and Wymenga (2009, 2013). The authors calculate detailed tariff equivalents of non-tariff barriers between the *USA* and the EU, using econometric techniques and business surveys. They also calculate the fraction of these non-tariff barriers that is reducible for each sector, i.e. the fraction of the trade cost that could in principle be eliminated by policy action. We collect information on sectors that can be easily matched to our classification shown in Table A.3. The sectors used, their non-tariff costs (in tariff equivalent terms) and the share of the costs that can be reduced are shown in Table A.1 in the Appendix.

As it is rather unlikely that the UK would face the same costs as the US in a case of withdrawal, in our optimistic scenario we assume that the UK would face one quarter (1/4) of the reducible cost faced by the USA, while in our pessimistic scenario we assume that they would face three quarters (3/4). We calculate the weighted average of these cost shares, using total EU/UK trade in each sector as weights and the subset of sectors shown in the Table A.1, which include several of the relevant sectors in the EU/UK relationship. This calculation leads to an increase in non-tariff costs of 2.01% and 6.04% in our optimistic and pessimistic scenarios, respectively. We then apply such costs to *all sectors* in our economy.

We also consider that the intra-EU trade costs are falling over time (Ilzkovitz, Dierx, Kovacs, and Sousa, 2007), and this rate is approximately 40% faster than in other OECD countries according to Méjean and Schwellnus (2009), which uses panel data on French firms to study price convergence in different markets between 1995 and 2004.[8] We consider the scenario that 10 years from now non-tariff barriers inside the EU would keep falling faster and the UK would not benefit from this evolution. In our pessimistic scenario we assume that intra-EU non-tariff costs continue to fall 40% faster than in the rest of the world. This may not necessarily be true since the OECD does not include countries like China, which has seen a rapid decrease in trade costs with other countries.

[8]They find that the rate of price convergence is -0.412 for OECD countries -0.593 for EU countries.

Hence, in our optimistic scenario we assume that intra-EU barriers fall only 20% faster than in the rest of the world.

To calculate this last counterfactual we need a measure of price differences across the EU. We use a rough measure from Eaton and Kortum (2002) of 49%[9], meaning that if the UK imported (exported) all goods from (to) other European countries prices would be 49% higher. Naturally, part of this price difference may not be reducible. We assume that the reducible proportion is 55%, which is the same share of non-tariff barriers that are actionable in the EU-USA trade case. To be conservative, in our pessimistic case we further assume that three quarters of the potentially reducible share will actually diminish throughout the years, while in the optimistic case we assume that such share is only one half. And to be even more conservative, we assume that the faster market integration will peter out in 10 years after Brexit. And then, again using the estimates of reducible price gaps from Méjean and Schwellnus (2009), we calculate the future falls of non-tariff barriers within EU, which lead to a fall of 12.77% and 6.04% in our pessimistic and optimistic scenarios respectively at year 10 after Brexit. [10]

Armed with these numbers, we simulate the model by feeding in the sequence of shocks in trade costs and tariffs for different scenarios of Brexit. The model then generates a sequences of changes in real consumption. This allows us to compute the welfare change due to Brexit using equation (28), assuming that the discount rate of future consumption is $\beta = 0.96$, which is a common value in the macro literature.

Our results are shown in Table A.5. Panel A shows the result of the optimistic scenario. We find that the welfare loss of the UK via the trade effect is 1.37%. How large are these numbers when compared to the costs generated by the EU membership? HM Treasury (2013) estimates that the net fiscal contribution of the UK to the EU is around 0.53% (or £ 8.6 billion) of the UK GDP (2013). We assume that the UK would keep contributing 83% of the current per capita contribution as Norway does in order to remain in the single market (House of Commons, 2013). This leads to a fiscal saving of about 0.09%. Taking this benefit into account, the UK would still lose a total of 1.28% in the case of an exit from the EU. We also calculate the implied loss per household. In 2015 the UK had a population of about 65m with 27m households and a GDP of £1.8 trillion. 1.28% of 1800/27 is £853 per household, which we round to £850 in the Table.

Panel B of Table A.5 shows the result of the pessimistic scenario. We see that the cost of a

[9] Table II, UK row average of the trade cost values.

[10] Please refer Appendix B for the details of the computation.

withdrawal doubles. The UK loses 2.92% via trade due to higher tariff, non-tariff trade barriers and exclusion from future further integration of the EU. Discounting the fiscal benefits still implies a total welfare loss of 2.61%. This is equivalent to £1,700 per household.

We have shown the welfare losses suffered by the UK. We also estimate the effect of Brexit on welfare for other countries again using equation (28). The results are shown in Figure C.1. Two groups of countries have relatively larger welfare losses. First, countries for which UK is an important trade partner, such as Ireland, Netherlands, Belgium, Denmark, Sweden, and Germany. Figure C.2 shows the average expenditure share of intermediates sourcing from the UK across sectors. These countries source relatively more intermediates from the UK, especially Ireland which sources about 12% of intermediate inputs from the UK. A second group of countries that lose out are those that do not trade much with the UK but exhibit a negative cross-sectoral correlation between the expenditure share on intermediates sourcing from the UK and the trade elasticity. Figure C.3 shows this correlation across countries. Countries such as Hungary, Czech Republic, and Slovakia tend to trade more with the UK in sectors with relatively low trade elasticity. In other words, if trade costs rise with the UK, they cannot easily substitute towards goods from other countries. Thus they will have a relatively larger welfare loss as the prices they pay will rise even if they trade relatively less with the UK.

Finally, countries outside EU tend to gain from Brexit, such as Russia, Turkey and China, although the numbers are very close to zero. This is because of a trade diversion effect due to the fact that the UK partially switches from trading with the EU to trading with non-EU countries (which in turn benefit from more trade with UK). This can be illustrated by Table A.6. As we can see, total British trade falls less than trade with the EU after Brexit.

4 Extensions and Robustness Checks

To check the robustness of our results to alternative assumptions, we first simulate the model for two different scenarios. The results is shown in Panel A of Table A.8. The first scenario that we simulate is the "Swiss Alternative". Switzerland is not in the EEA but has many bilateral agreements with the EU, which give it some access to the single market. Like Norway, it has to adopt all the regulations covering those parts of the single market it participates in and also allows free movement of labour. It does, however, benefit from a lower fiscal transfer (about 40% of the UK's contribution on a per capita basis). On the other hand, it does not have free trade in services with the EU, which would be a disadvantage for an economy like the UK, which has a comparative advantage in services. We simulate the effects of Brexit using Switzerland as an alternative optimistic scenario.

The result is very similar to the benchmark optimistic scenario - a loss of income of 1.28%. Although the fiscal transfers are lower than for Norway (40% of 0.53% = 0.31%) , these are more than offset by higher costs of trade in services (a total welfare loss from lower trade of 1.6% vs. 1.37%).

Another scenario that we consider is what we call the Big Bang scenario. Under this scenario, we assume that, if Brexit happens, the UK and the EU would impose MFN tariffs on each other and the non-tariff trade barriers between the UK and the EU would rise to the reducible level between the USA and the EU (+8.06%). Integration in the EU would continue to be 40% faster than in the rest of world and 100% of the reducible price gaps could be reduced. However, the UK would not benefit from such further integration. We assume that further integration would happen in the year following Brexit, which implies that we are simulating the upper bound of welfare loss for UK in our model. In this scenario we find that the UK welfare loss is about 3.5%.

Brexit campaigners have argued that the UK could neutralize the trade effect by unilaterally liberalizing with all other countries. We check whether this is the case by removing all UK import tariffs. We measure these import tariffs by constructing the sectoral MFN tariff as the weighted average of HS 6-digit level UK imports from non-EU countries. The results are shown in Table A.2. The overall weighted average UK MFN import tariff is around 3%. Feeding these tariffs into our model for both the optimistic and pessimistic scenario, we find the effect of unilateral liberalization is very limited as shown in Panel B of Table A.8. The welfare gain from removing the MFN import tariff of the UK is just around 0.3%, far from neutralizing the adverse trade effect of Brexit. In the optimistic case the income loss is 1% instead of 1.3% and in the pessimistic case the loss if 2.3% instead of 2.6%. This is not surprising given that UK's import tariffs are already very low.

In Panel C, we simulate the welfare loss of UK using alternative values of discount factor β and fiscal benefits. So far, we have used a real interest rate of 4% which is standard in the macro literature, but currently real interest rates are much lower than this, near zero in many cases. Using a lower interest rate increases the costs of Brexit, because it gives larger weights to future losses of income. For example, using a real interest rate of 1% leads to a welfare loss of 2.68% in the optimistic case. Hence, given the current low interest rate, the results that we present in Table A.5 might actually understate the real loss.

Finally, in the second column of Panel C we show that varying the fiscal benefit from 0.31% to 0.53% (to account for different available estimates) makes little difference to our results.

4.1 Summary

In this section, we vary parameters within plausible ranges to test the robustness of our findings. Although the exact magnitude of the welfare loss changes in each experiment, it is consistently negative with a loss of income ranging between 1% and 4%. The qualitative finding that British households will be poorer after Brexit is robust, the only question is exactly how much poorer they will be.

5 Reduced Form Estimates

In the previous section we attempted to quantify the welfare effects of the UK leaving the EU using a quantitative model of international trade. An alternative approach is to use existing empirical estimates of the effects of EU membership to infer the impact of leaving the EU on UK income. In particular, we can decompose the question into two parts. First, what effect will leaving the EU have on the UK's trade with the rest of the world? Second, what is the effect of changes in trade levels on income? There exist substantial literatures addressing both the effect of joining an economic integration agreement (EIA), such as the EU, on trade and the effect of trade on income.

Suppose that if the UK leaves the EU it will become a member of the European Free Trade Association (EFTA). Does EU membership cause a country to trade more with other EU members than EFTA membership? Baier, Bergstrand, Egger, and McLaughlin (2008) address exactly this question using a gravity model of bilateral trade augmented with dummy variables for which EIAs the exporter and importer belong to. In particular, they include dummy variables for both countries being in the EU, both countries being in EFTA, one country being in the EU and the other in EFTA and for both countries belonging to any other EIA. Importantly, they control for endogeneity of selection into the formation of EIAs using country-pair fixed effects with panel data. They find robust evidence that being a member of the EU leads a country to trade significantly more with other members of the EU than if it were only a member of EFTA. Quantitatively, their estimates imply that leaving the EU and joining EFTA would reduce the UK's trade with EU members by 25%.[11]

[11]This figure is calculated using the estimates in Table 6, column 1. Both countries being in the EU increases trade by $e^{0.48} - 1 = 62\%$, while one country being in the EU and the other in EFTA increases trade by $e^{0.19} - 1 = 21\%$.

To predict the change in the UK's overall trade we also need to know how leaving the EU would affect the UK's trade with non-EU members. Baier, Bergstrand, Egger, and McLaughlin (2008) estimates suggest that whether a country is a member of the EU or EFTA does not have a significant effect on its trade with EFTA members. However, their estimates do not address how EU membership affects trade with countries outside of both the EU and EFTA. Structural gravity models such as that developed by Egger, Larch, Staub, and Winkelmann (2011) can be used to infer the general equilibrium effects of EIAs on trade between all country-pairs, but we are not aware of any work that applies the structural gravity methodology to estimate the effects of EU membership. Instead, we will rely on reduced form gravity model estimates of the trade diversion effects of EIAs. Studies of trade diversion typically find little evidence that joining an EIA leads to a reduction in trade with countries outside of the EIA. For example, Magee (2008) fails to find robust evidence of significant trade diversion effects from EIAs. Therefore, we will assume that leaving the EU will not affect the UK's trade with the rest of the world.

To quantify the effect of trade on income we will use the estimates of Feyrer (2009). Using data on the air and sea distances between countries, Feyrer (2009) uses changes in the cost of shipping goods via air relative to sea as an instrument for trade in a regression of income on trade. Since the instrument is time varying, Feyrer (2009) is able to improve upon the cross-section estimates of Frankel and Romer (1999) by using country fixed effects to control for time invariant unobservable that affect income levels. Feyrer (2009) concludes that the elasticity of income to trade is probably between one-half and three-quarters. In other words, a 10% increase in trade increases income by 5% to 7.5%. The estimation strategy of Feyrer (2009) implies that his estimates capture both the direct effect of higher trade on income and also other indirect effects of increased proximity between countries such as variation in FDI and knowledge diffusion. Thus, the estimates we obtain in this section should be interpreted as including some of the non-trade channels through which leaving the EU will affect UK income in addition to the direct effect of changes in the UK's trade.

Combining these numbers we can obtain a reduced form estimate of the effect of leaving the EU and joining EFTA on UK income. Since 50.4% of the UK's trade is with the EU, a 25% fall in trade with EU members will reduce the UK's overall trade by 12.6%. Combining this with the estimate in Feyrer (2009) that the elasticity of income to trade is between one-half and three-quarters implies

Therefore, if a country leaves the EU and joins EFTA trade with EU members declines by $(e^{0.19} - e^{0.48})/e^{0.48} = 25\%$. To avoid confusion when interpreting the coefficient estimates in Baier, Bergstrand, Egger, and McLaughlin (2008) note that their EEA dummy variable is defined equal to one for a country pair when one country is in EFTA and the other country is in the EU. Baier, Bergstrand, Egger, and McLaughlin (2008) do not estimate the effects of EEA membership on trade, probably because the EEA was only established in 1994 and they use data from 1960-2000.

that leaving the EU and joining EFTA will reduce the UK's income by between 6.3% and 9.5%.[12] Interestingly, these calculations are similar to estimates of the historical benefits of EU membership for the EU. For example, (Crafts, 2016) considers a range of papers that have sought to estimate historically what the net benefit has been of EU membership. He concludes that the there was an increase in UK GDP of around 8% to 10%.

The reduced form approach used in this section has two principal advantages over the structural approach used earlier in the paper. First, it requires less detailed assumptions about what the relationship between the UK and the EU would be following a UK exit. The structural estimates required assumptions about both the future level of tariffs between the EU and the UK and the extent to which the UK would share in future reductions in non-tariff barriers within the EU. By contrast, the reduced form estimates are based on the simple and plausible assumption that if the UK leaves the EU it will join EFTA. Second, while the quantitative trade model used above is designed to capture only the static gains from trade, reduced form estimates of the effect of trade on income should capture both static and dynamic effects.

The disadvantage of the reduced form approach is that it relies on the existence of unbiased empirical estimates. While we have based our calculations on estimates obtained using best practice empirical methodologies, sampling error and identification challenges inevitably mean that some degree of uncertainty must be attached to the estimates. Overall, the calculations in this section should be viewed as a robustness check on the plausibility of the predictions obtained from the quantitative trade model. The reduced form estimates of the income effect of leaving the EU are higher than those obtained from the quantitative trade model, but they reinforce the conclusion that leaving the EU is likely to have a sizeable negative effect on UK welfare.

6 Conclusion

We have looked at different ways of estimating the change in UK living standards following a decision to leave the EU. Using the Costinot and Rodriguez-Clare (2013) methodology, we generate counterfactual scenarios and show that future losses in the UK due to this move can sum up to 1.28% of the GDP in real terms in our optimistic scenario, and to 2.61% in our pessimistic one.

[12] These estimates will understate the cost of leaving the EU if Baier, Bergstrand, Egger, and McLaughlin (2008) underestimate the decline in trade from leaving the EU and joining EFTA. Using the estimates in Table 5, column 1 of Baier, Bergstrand, Egger, and McLaughlin (2008) implies the UK's trade with EU members would decline by $(e^{0.19} - e^{0.65})/e^{0.65} = 37\%$ which implies a decline in UK income of between 9.3% and 13.9%. We chose to use the estimates in Table 6, column 1 to obtain a more conservative estimate of the costs of Brexit.

There are good reasons for thinking these under-estimate the real costs of Brexit as the evidence looking at the historical impact of countries joining the EU has generated more trade and more income than the static trade exercises we perform here would suggest. Using the reduced form approach finds welfare losses of between 6.3% and 9.5%.

In any case, we should have in mind that these numbers are likely to be larger in reality, since many other welfare improving channels associated with EU trade such as immigration, increases in productivity, increases in R&D intensity, vertical production chains, to cite just a few, are not considered in our analysis.

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Appendix

A Tables

Table A.1: Sector and Non-tariff Barriers (NTB) used in the Counterfactuals

Sector	*NTB Cost EU+/USA (tariff equivalent)*	*Reducible share of NTB*	*Weight (total trade UK/EU)*
Transport Equipment	22.1%	0.53	95723
Chemicals and Chemical Products	23.9%	0.63	74797
Post and Telecommunications	11.7%	0.70	8733
Electrical and Optical Equipment	6.5%	0.41	61506
Financial Intermediation	11.3%	0.49	50145
Food, Beverages and Tobacco	5.8%	0.53	56463
Construction	4.6%	0.38	3760
Renting of Machinery & Equip. and Other Business Activities	14.9%	0.51	72628
Services Nec (*)	4.4%	0.37	13561
Basic Metals and Fabricated Metal	11.9%	0.62	44769
Textiles and Textile Products; Leather, Leather and Footwear	19.2%	0.50	20178
Wood and Products of Wood and Cork	11.3%	0.60	3413
Overall Weighted Average	14.7%	0.55	–

Source: WIOD and authors' compilation of a subset of the sectors presented in Tables 3.3 and 4.2 of Berden, Francois, Tamminen, Thelle, and Wymenga (2009).
Notes: The Table provides non-tariff costs (in tariff equivalent terms) of trade flows from the USA to the EU+ (column 1). It also provides the share of costs that are potentially reducible (column 2). In our counterfactuals we assume either (i) that after Brexit the UK faces 1/4 of the reducible costs of the USA (optimistic scenario) or (ii) that after the exit the UK faces 3/4 of the reducible costs seen by the USA (pessimistic scenario). We then use total EU trade as weights (column 3) to compute a weighted average of these costs and apply to all sectors in all our counterfactuals. EU is defined as EU 28 minus the UK. EU+ includes the UK. Total trade in column (3) is the sum of all imports from the rest of the EU to the UK plus all exports from the UK to the EU (in millions of US dollars). The overall weighted averages in the final row use column (3) numbers as weights.
(*) Includes 'Repair of Household Goods'

Table A.2: UK MFN tariff with Non-EU Countries

Sectors	Import Tariff	Export Tariff
Agriculture, Hunting, Forestry and Fishing	1.07	4.02
Mining and Quarrying	0.00	0.00
Food, Beverages and Tobacco	6.19	2.08
Textiles and Textile Products; Leather, Leather and Footwear	10.70	8.73
Wood and Products of Wood and Cork	2.74	3.16
Pulp, Paper, Paper , Printing and Publishing	0.07	0.06
Coke, Refined Petroleum and Nuclear Fuel	2.51	3.36
Chemicals and Chemical Products	2.46	1.89
Rubber and Plastics	5.25	5.28
Other Non-Metallic Mineral	4.79	3.49
Basic Metals and Fabricated Metal	1.47	1.00
Machinery, Nec	2.36	2.00
Electrical and Optical Equipment	1.84	1.70
Transport Equipment	5.43	6.26
Manufacturing, Nec; Recycling	1.45	1.76
Overall Weighted Average	3.09	2.60

Source: UN Comtrade comtrade.un.org/ and WTO http://tariffdata.wto.org/.
Note: Tariff used in the case of UK unilaterally liberalization. Actual applied MFN tariff for HS6 industries are aggregated to WIOD sectors using the trade between UK and non-EU countries as weights. In other words we use the total imports to the UK from non-EU countries at the HS6 level to weight the import tariffs and the total exports from the UK to non-EU countries at the HS6 level to weight the export tariffs.

Table A.3: UK Trade Statistics in 2011

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Total		*Imports*			*Exports*	
Sector	*EU Trade*	*Non-EU*	*EU*	*MFN Tariff*	*Non-EU*	*EU*	*MFN Tariff*
Goods							
Transport Equipment	95,723	30,753	60,382	8.09%	49,468	35,341	7.22%
Chemicals and Chemical Products	74,797	17,079	34,854	2.71%	24,265	39,943	2.16%
Electrical and Optical Equipment	61,506	36,176	38,057	1.97%	27,783	23,449	1.55%
Food, Beverages and Tobacco	56,463	14,706	42,294	7.26%	14,479	14,168	4.96%
Coke, Refined Petroleum and Nuclear Fuel	45,610	12,432	17,194	2.69%	11,299	28,416	2.81%
Basic Metals and Fabricated Metal	44,769	16,890	26,150	2.05%	18,202	18,619	1.89%
Machinery, Nec	39,624	13,809	24,717	2.05%	24,328	14,907	2.13%
Mining and Quarrying	28,679	48,929	8,512	0.00%	17,976	20,167	0.00%
Textiles and Textile Products; Leather, Leather and Footwear	20,178	23,282	11,912	9.58%	4,074	8,267	9.70%
Rubber and Plastics	16,042	5,400	9,290	5.35%	4,133	6,751	5.05%
Manufacturing, Nec; Recycling	15,909	9,188	9,730	1.71%	6,889	6,179	1.69%
Pulp, Paper, Paper , Printing and Publishing	15,538	4,516	10,539	0.04%	7,546	4,999	0.10%
Agriculture, Hunting, Forestry and Fishing	11,432	6,968	8,080	5.90%	1,677	3,352	5.63%
Other Non-Metallic Mineral	5,673	1,909	3,553	3.78%	1,959	2,120	3.32%
Wood and Products of Wood and Cork	3,413	1,493	2,942	2.35%	237	471	3.62%
Total Trade in Goods	*535,356*	*243,530*	*308,206*		*214,315*	*227,149*	
Services							
Renting of Machinery & Equip. and Other Business Activities	72,628	28,017	19,618	-	31,989	53,009	-
Financial Intermediation	50,145	18,285	3,281	-	50,761	46,864	-
Services Nec (4)	13,561	10,790	6,524	-	8,548	7,036	-
Post and Telecommunications	8,733	5,094	2,521	-	2,146	6,212	-
Air Transport	8,304	5,922	6,790	-	6,073	1,514	-
Hotels and Restaurants	6,196	18,319	4,312	-	10,352	1,884	-
Retail, Wholesale and Repair Activities Nec (1)	4,701	3,770	4,110	-	2,302	591	-
Other Supporting and Auxiliary Transport Activities (3)	4,321	1,318	1,706	-	1,742	2,615	-
Construction	3,760	587	1,890	-	383	1,869	-
Electricity, Gas and Water Supply	2,025	686	1,563	-	340	462	-
Retail Trade, Except of Motor Vehicles and Motorcycles (2)	1,216	457	936	-	989	280	-
Inland Transport	1,002	6,703	782	-	3,335	220	-
Real Estate Activities	967	1,752	191	-	97	776	-
Health and Social Work	906	2,007	831	-	410	74	-
Education	357	856	214	-	3,323	142	-
Water Transport	341	3,705	256	-	13,588	85	-
Total Trade in Services	*179,163*	*108,268*	*55,525*		*136,378*	*123,633*	
Total Trade	*714,519*	*351,798*	*363,731*		*350,693*	*350,782*	

Source: WIOD, WTO and UN Comtrade.

Notes: Table provides 2011 UK import and export values with EU and non-EU, as well as tariff costs for all WIOD sectors. All values in millions of USD. EU is defined as EU 28 minus the UK and Croatia. Column (1) equals the sum of columns (3) and (6). Tariffs by product are collected from the WTO database. Tariffs shown are weighted averages of products tariffs, where we use the import and export values by product between the UK and the EU as weights to compute the numbers seen in columns 5 and 8, respectively. Trade by product comes from UN Comtrade.

(1) Retail Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Commission Trade, Except of Motor Vehicles and Motorcycles

(2) Includes 'Repair of Household Goods'

(3) Includes 'Activities of Travel Agencies'

(4) Public Admin and Defence; Compulsory Social Security; Other Community, Social and Personal Services; Private Households with Employed Persons

Table A.4: Trade Elasticity for each sector

WIOD31 sector code	Sectors	Trade Elasticity
1	Agriculture, Hunting, Forestry and Fishing	8.11
2	Mining and Quarrying	15.72
3	Food, Beverages and Tobacco	2.55
4	Textiles and Textile Products; Leather, Leather and Footwear	5.56
5	Wood and Products of Wood and Cork	10.83
6	Pulp, Paper, Paper , Printing and Publishing	9.07
7	Coke, Refined Petroleum and Nuclear Fuel	51.08
8	Chemicals and Chemical Products	4.75
9	Rubber and Plastics	1.66
10	Other Non-Metallic Mineral	2.76
11	Basic Metals and Fabricated Metal	7.99
12	Machinery, Nec	1.52
13	Electrical and Optical Equipment	10.6
14	Transport Equipment	0.37
15	Manufacturing, Nec; Recycling	5
16	Electricity, Gas and Water Supply	5
17	construction	5
18	Retail Sale of Fuel; Wholesale Trade, Commission Trade, including Motor Vehicles & Motorcycles	5
19	Retail Trade, Except of Motor Vehicles & Motorcycles; Repair of Household Goods	5
20	Hotels and Restaurants	5
21	Inland Transport	5
22	Water Transport	5
23	Air Transport	5
24	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	5
25	Post and Telecommunications	5
26	Financial Intermediation	5
27	Real Estate Activities	5
28	Renting of M&Eq and Other Business Activities	5
29	Education	5
30	Health and SocialWork	5
31	Public Admin, Defence, Social Security and othe public service	5

Source: The aggregation of the sectors are the same as (Costinot and Rodriguez-Clare, 2013). The trade elasticities for the tradable sectors are estimated by Caliendo and Parro (2014). For the service sector, we follow (Costinot and Rodriguez-Clare, 2013) to set them as 5.

Table A.5: Welfare change of UK Due to Brexit

Panel A: Optimistic Scenario	
Trade Effects	-1.37%
Fiscal Benefit	0.09%
Total Welfare Change	*-1.28%*
Income change per household	$-£850$

Panel B: Pessimistic Scenario	
Trade Effects	-2.92%
Fiscal Benefit	0.31%
Total Welfare Change	*-2.61%*
Income change per household	$-£1,700$

Notes: Counterfactuals changes in welfare, measured by consumption equivalent as specified by equation (28) with $\beta = 0.96$. Fiscal benefit information comes from HM Treasury (2013). EU is defined as EU 28 minus the UK and Croatia.
Panel A shows an optimistic scenario where UK could negotiate a deal like Norway and tariffs remain zero. But non-tariff barriers increases to 1/4 of the reducible barriers faced by USA exporters to the EU (2.01% increase). Further, the UK does not benefit from further integration of EU where non-tariff barriers will fall 20% faster than in the rest of the world (5.68% lower in 10 years). For the fiscal effect,we assume that UK could save 17% from the fiscal contribution to the EU (same as Norway) which is 0.09% of UK GDP.
Panel B shows a pessimistic scenario where the UK and EU impose MFN tariffs on each other (see Table A.3). Non-tariff barriers increases to 3/4 of the reducible barriers faced by USA exporters to the EU (6.04% increase). Further, the UK is excluded from further integration of EU where non-tariff barriers will fall 40% faster than in the rest of the world (12.77% lower in 10 years). For the fiscal effect, we assume that the UK saves more on fiscal contribution to EU budget which is 0.31% of UK GDP.

Table A.6: Change in UK Trade Flow after Brexit

Scenario	Horizon	Total British Export	Total British Import	Export to EU	Import from EU
Optimistic Scenario	Short Run	-4%	-5%	-11%	-10%
	Long Run	-8%	-8%	-25%	-22%
Pessimistic Scenario	Short Run	-12%	-12%	-31%	-29%
	Long Run	-15%	-14%	-44%	-38%

Notes: short run horizon is 1 year after Brexit and long run horizon is 10 years after Brexit.

Table A.7: Impact of Brexit on living standards in different regions

	Optimistic		Pessimistic	
	Change in % GDP	Change in GDP (£ bn)	Change in % GDP	Change in GDP (£ bn)
UK	-1.37%	-25.7	-2.92%	-54.8
All EU countries except UK	-0.12%	-11.6	-0.29%	-28.1
Non-EU countries	0.01%	3.7	0.02%	7.4

Notes: Same assumptions as in Pessimistic and Optimistic scenario in Table A.5 GDP levels from IMF in £ 2014 https://en.wikipedia.org/wiki/List_of_countries_by_GDP_%28nominal%29.

Table A.8: Robustness on welfare change of UK Due to Brexit

Panel A: Alternative scenarios

Scenarios	A Swiss Alternative	Big Bang
Trade effects	−1.60%	−4.02%
Net UK fiscal contribution	0.31%	0.53%
Welfare Loss of UK	−1.28%	−3.49%

Panel B: Unilateral liberalisation of UK

Scenarios	optimistic	pessimistic
Trade effects	−1.37%	−2.92%
Fiscal benefits	0.09%	0.31%
Unilateral liberalisation	0.30%	0.32%
Welfare Loss of UK	−0.98%	−2.29%

Panel C: UK welfare loss under different parameters

Scenarios	optimistic	pessimistic
Discount factor: $\beta = 0.99$	−1.42%	−2.68%
Size of UK fiscal contribution to the EU	−1.32%	−2.39%

Notes: Panel A shows the results of the Swiss Alternative. Under such a scenario, the UK and EU still impose zero tariffs on goods flows. But unlike the optimistic scenario, the UK net fiscal contribution to EU would be lower but the non-tariff barriers would be higher for services. To be precise, we assume the non-tariff trade barriers for goods would be the same as the optimistic scenario and the non-tariff trade barriers for services would be the same as the pessimistic scenario. Further, the UK saves 60% of the current fiscal transfer of 0.53% of GDP. In the Big Bang scenario, UK and EU trade is subjected to MFN tariff. Non-tariff barriers increase by 8.01% between UK and EU but decrease between all other EU members by 15.88% following the year after Brexit.
Panel B shows the results of UK unilaterally liberalizing to all other countries. That is the UK imposes zero tariffs on all imported goods. The tariffs between UK and non-EU countries are shown in Table A.2.
Panel C shows the welfare results for the optimistic and pessimistic scenario as we specified in Table A.5. We first change the discount factor β from 0.96 to 0.99. In the second case, we alternate the size of the net fiscal transfer from UK to the EU from 0.53% to 0.31% of GDP for the optimistic scenario and from 0.31% to 0.53% of GDP for the pessimistic scenario.

Table A.9: Aggregation of Regions

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

Notes: We aggregate the WIOD regions shown in column(1) to those shown in column(3).

B Future fall in non-tariff trade costs

We assume that trade costs

$$\tau = \tau^{UR}\tau^{R}$$

where τ^R is the reducible component and τ^{UR} is the non-reducible component hence constant overtime. For the reducible component, it is decaying in the following manner

$$\ln(\tau_t^R) = (1-d)^t \ln(\tau_0^R)$$

where d controls the speed of decaying. Then at period t, the change in the reducible iceberg trade cost is given by:

$$\Delta\tau_t^R = \tau_t^R - \tau_0^R.$$

[13] The shock to the trade cost is

$$\widehat{\tau}_t = \frac{\tau_t'}{\tau} = \frac{\tau'^R_t}{\tau^R}$$

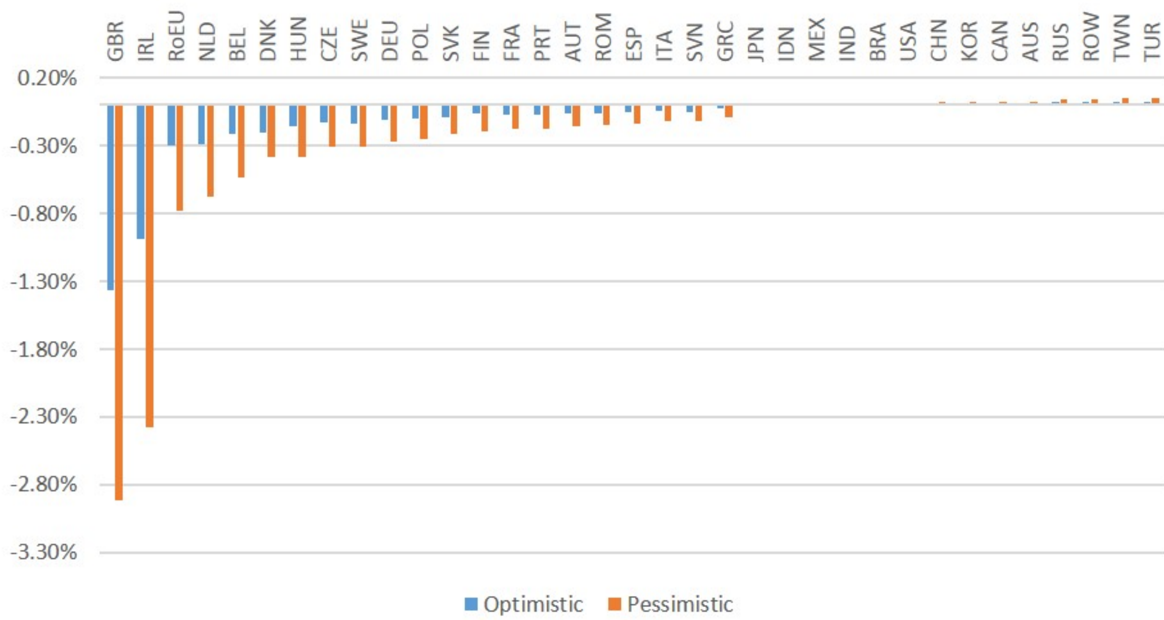
where $\tau'^R_t = \tau_0^R + \Delta\tau_t^R$.

As mentioned, Méjean and Schwellnus (2009) find that the rate of price convergence is -0.412 for OECD countries -0.593 for EU countries. Thus the rate of price convergence in EU is about 40% faster (0.593-0.412=0.182, 0.182/0.412=0.44). To capture the relatively faster integration of EU, we set $d^{pes} = 0.182$ in our pessimistic scenario. We set $d^{opt} = 0.091$ in our optimistic scenario so the speed of price convergence is 20% faster than other countries. In our pessimistic scenario, we assume that 3/4 of the reducible trade costs of UK and EU could be reduced. Since $\tau = 1.49$ according to (Eaton and Kortum, 2002), and according to Méjean and Schwellnus (2009), 55% of the trade cost is reducible, thus we have $\tau_0^{R,pes} = 1+0.49*0.55*3/4 = 1.20$. In our optimistic scenario, we assume that only 1/2 of the reducible price gap could be reduced, thus $\tau_0^{R,opt} = 1+0.49*0.55*1/2 = 1.13$. Assuming that faster EU integration peters out in 10 years after Brexit($d = 0$ after year 10) as explained in our main text, using the formulas above, we could find out the whole sequence of $\widehat{\tau}_t$ to be fed into our model.

[13] For example, at year 10, $\Delta\tau_{10}^R = \tau_0^R - \tau_0^{R(1-d)^{10}}$.

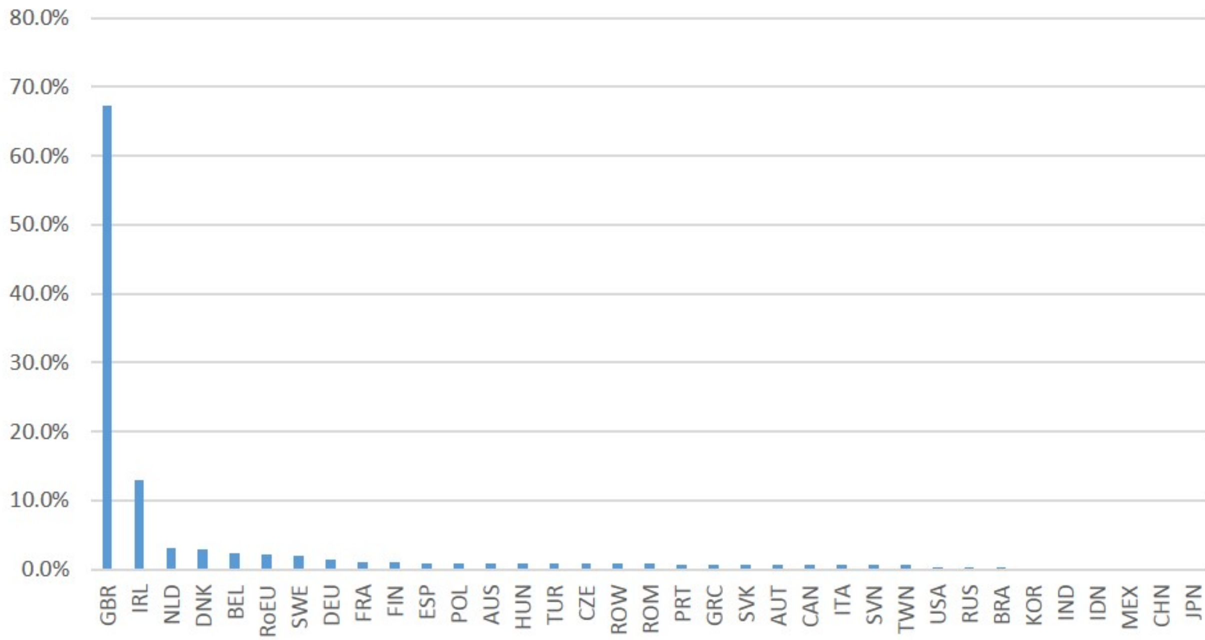
C Graphs

Figure C.1: Welfare loss across countries



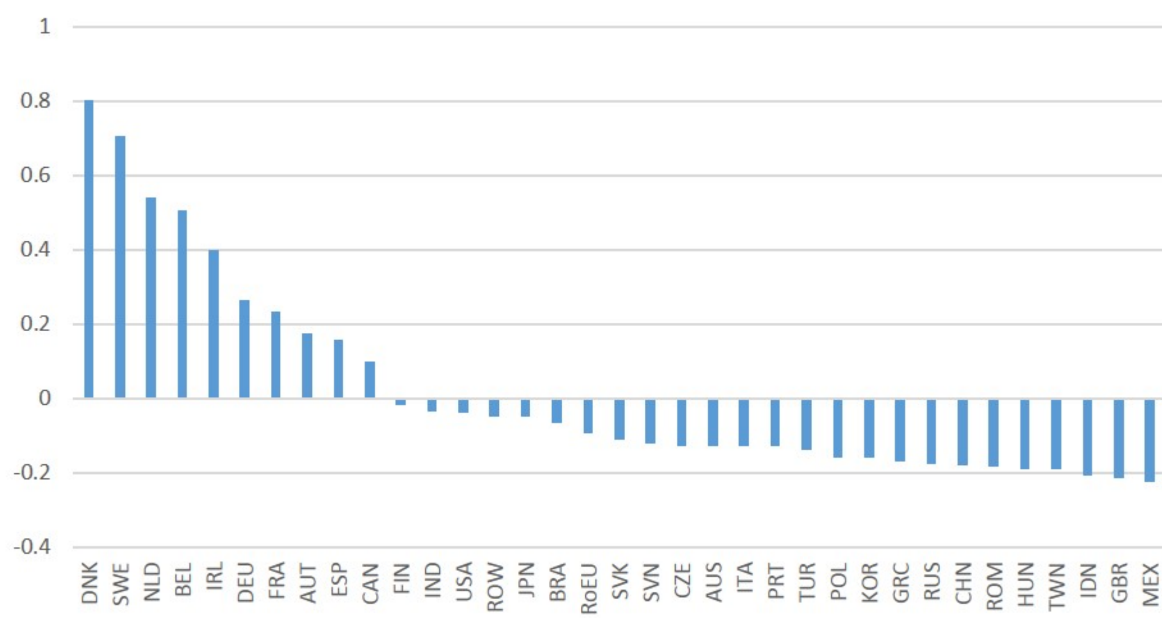
Notes: same assumptions as in notes to Table A.5 except net fiscal savings not included. The list of countries could be found in A.9

Figure C.2: Average share of intermediates sourcing from UK across sectors



Notes: The share is the simple average of input value share sourcing from the UK across 31 WIOD sectors.

Figure C.3: Correlation between expenditure share on UK goods and trade elasticity



Notes: The figure plots the expenditure share on UK goods with the trade elasticity for each country.