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The Costs and Benefits of Leaving the EU: Trade Effects

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Abstract

This paper estimates the welfare effects of Brexit, focusing on trade and fiscal transfers. We use a standard quantitative general equilibrium trade model with many countries and sectors and trade in intermediates, as in Costinot and Rodríguez-Clare (2014). We simulate a range of counterfactuals reflecting alternative options for EU-UK relations following Brexit. Welfare losses for the average UK household are 1.3% if the UK remains in the EU's Single Market like Norway (a "soft Brexit"). Losses rise to 2.7% if the UK trades with the EU under World Trade Organization rules (a "hard Brexit"). A reduced form approach that captures the dynamic effects of Brexit on productivity more than triples these losses and implies a decline in average income per capita of between 6.3% and 9.4%, partly via falls in foreign investment. These negative effects are widely shared across the entire income distribution and are unlikely to be offset from new trade deals.

Keywords: Trade, Brexit, General equilibrium
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1 Introduction

On June 23^{rd} 2016 the United Kingdom (UK) voted to leave the European Union (EU), a club it had been a member of since 1973. Prime Minister David Cameron resigned the next morning and was replaced by Theresa May. The vote sent shock waves around the world. Sterling fell immediately and by the end of the year its dollar value was around 17% lower than on the night before the referendum. On March 29^{th} 2017 the UK formally notified the EU of its intention to withdraw from the union under Article 50 of the Lisbon Treaty, triggering the start of a two year window for the UK to negotiate the terms of its divorce with the EU.

The debate over the UK's membership of the EU raised a number of political questions. Supporters of Brexit argued that leaving would give the UK greater freedom to determine its own policies to reflect the UK's national interests. Opponents of Brexit stressed the contribution the EU has made to ensuring peace within Europe and argued that being part of the EU magnified the UK's influence on the world stage. These are important issues, but they are not the subject of this paper. Instead, we focus on understanding the economic costs and benefits of Brexit, in particular those resulting from changes in trade.

To estimate these economic costs and benefits of Brexit, we take a medium to long-run perspective and abstract away from the effects of increased uncertainty and the transition to a new equilibrium. Hence, we do not build a dynamic macro-econometric model that includes these effects,[1] but focus on quantifying the key channels through which the UK leaving the EU may affect income and consumption ten years or more after Brexit is expected to occur in 2019.

Since it is difficult to know what the exact form of a post-Brexit deal between the UK and the EU will be, we consider several possible counterfactual scenarios. The two main ones we analyse are an optimistic "soft Brexit" and a more pessimistic "hard Brexit". A soft Brexit is where the UK continues to be a member of the EU Single Market like other non-EU members of the European Economic Area (EEA), such as Norway. A hard Brexit is where the UK trades only under World Trade Organization (WTO) rules like the United States (US) or Japan. A soft Brexit would lead to smaller increases in trade barriers between the UK and the EU than a hard Brexit, but would also require the UK to continue making fiscal contributions to the EU budget. In January 2017 Prime Minister Theresa May announced that the UK's goal in its negotiations with the EU would be to leave the Single Market while still maintaining free trade with the EU to the greatest extent

[1] For example, Steinberg (2017) models the uncertainty costs of Brexit and finds they are small compared to the long-run effects.

possible (May, 2017), thus making a hard Brexit appear more likely than a soft Brexit. The key political constraint preventing a soft Brexit is that Single Market membership requires allowing free movement of people with the EU, which the UK government opposes.

Our methodology is based on Costinot and Rodríguez-Clare (2014). We set up a general equilibrium trade model which covers 31 sectors and aggregates the world into 35 regions. We model the effects of alternative post-Brexit scenarios by simulating changes in trade costs and calculating how each scenario affects welfare as measured by real consumption per capita. The welfare loss from Brexit is obtained by comparing welfare when the UK remains a member of the EU with welfare following Brexit. We find that increases in bilateral tariffs and non-tariff barriers (NTBs) between the UK and the EU and the exclusion of the UK from future EU integration leads to a fall in UK welfare even after accounting for the savings the UK makes from lower fiscal transfers to the EU. The estimated welfare losses range from -1.3% in the optimistic soft Brexit scenario to -2.7% in the pessimistic hard Brexit scenario. We carry out a large number of robustness checks based on alternative assumptions regarding the post-Brexit EU-UK trade deal. In all cases Brexit reduces the welfare of the average citizen.

The UK is not the only loser from Brexit. Within the EU, countries that trade intensively with the UK are most affected. For example, in the pessimistic scenario Ireland's welfare declines by 2.4%. Nevertheless, the costs to the UK are much larger than those for the rest of the EU, implying the UK has the most to lose from Brexit. Countries outside the EU tend to experience a very small welfare gain, mostly due to a trade diversion effect. As a whole, however, the world beyond Britain's shores is poorer after Brexit.

In our quantitative model, trade liberalisation tends to increase welfare because it allows countries to specialise in their areas of comparative advantage and reduces the costs of goods, services and intermediate inputs (Eaton and Kortum, 2002). Our baseline calculations, however, leave out many factors that could lead to further productivity and welfare losses following Brexit. For example, reductions in the variety of goods and services (Krugman, 1980), weaker competition (Melitz, 2003), the erosion of vertical production chains (Melitz and Redding, 2014), falls in foreign direct investment (FDI) (Wacziarg, 1998), slower technology diffusion (Sampson, 2016; Wacziarg, 1998), less learning from exports (Albornoz, Calvo Pardo, Corcos, and Ornelas, 2012; Egger, Larch, Staub, and Winkelmann, 2011) or lower Research and Development (Bloom, Draca, and Van Reenen, 2015; Keller, 1999, 2002).

An alternative way to evaluate the impact of Brexit and take into account some of these addi-

tional effects of trade integration (which we label "dynamic effects") is to use the results of reduced form empirical studies of the effects of EU membership on trade. 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 would fall by about a quarter. Combining this with the estimates from Feyrer (2009) implies that leaving the EU (and joining EFTA) would reduce UK income per capita by between 6.3% and 9.4%. These estimates are much higher than the costs obtained from the static analysis, implying that dynamic effects from trade are important. We show evidence that lower FDI in the UK following Brexit is likely to account for part of this difference.

Our main analysis focuses on aggregate outcomes, but we also discuss the possible distributional effects of Brexit through immigration, price changes that differentially affect the consumption baskets of rich and poor households, and relative wage effects. We conclude that the pain of Brexit is likely to be shared quite democratically across the income distribution.

The structure of the paper is as follows. We first discuss the options for UK-EU trade relations after Brexit in section 2. We lay out the conceptual framework we use to model the welfare effects of Brexit in section 3, present the data and counterfactual analysis in Section 4 and undertake robustness checks in section 5. Section 6 presents our reduced form estimates and section 7 discusses distributional effects. Finally, section 8 offers some concluding comments.

2 Options for UK-EU Trade Relations After Brexit

It is highly uncertain what Brexit will end up meaning for the terms under which the UK trades with the EU. Dhingra and Sampson (2016) review the alternatives facing the UK and the EU. Broadly speaking there are three types of relationship to choose from. The UK could remain part of the Single Market like Norway; the UK could negotiate bilateral agreements with the EU as Switzerland and Canada have done; or the UK and the EU could trade under World Trade Organisation terms. In this section we describe how each of these options would affect trade barriers between the UK and the EU. As will become clear, the key trade-off the UK will face after Brexit is the same trade-off it faced within the EU. There are economic benefits from integration, but obtaining these benefits comes at the political cost of giving up control over some areas of policy. Inside or outside the EU, this trade-off is inescapable.

2.1 Soft Brexit: Single Market Membership and the Norway Option

The European Economic Area was established in 1994 to give countries that are not part of the EU a way to join the Single Market. The EEA comprises all members of the EU together with three non-EU countries: Iceland, Liechtenstein and Norway. There is free movement of goods, services, people and capital within the EEA and, since EEA members belong to the Single Market, they must abide by the EU's economic rules including legislation regarding employment, consumer protection, product standards, environmental and competition policy.

Joining the EEA would allow the UK to remain part of the Single Market while not participating in other forms of European integration. EEA membership does not oblige countries to participate in the monetary union, the EU's common foreign and security policy or the EU's justice and home affairs policies. EEA members also do not participate in the Common Agricultural Policy. EEA members effectively pay a fee to be part of the Single Market. They do this by contributing to the EU's regional development funds and contributing to the costs of the EU programmes in which they participate. In 2011, Norway's contribution to the EU budget was £106 per capita, only 17% lower than the UK's net contribution of £128 per capita (House of Commons, 2013).

If the UK joins the EEA, UK-EU goods trade would continue to be tariff free and there would be no new barriers to services trade between the UK and the EU. In particular, UK financial institutions would retain the passporting rights (see subsection 5.5 below) that allow them to provide services throughout the EEA. Non-tariff barriers between the UK and the EU would also remain low because the UK would continue to follow the EU's economic rules and policies. There would be some new non-tariff barriers on UK-EU trade. EEA members are not part of the EU's Customs Union, which means they can set their own external tariff and conduct their own trade negotiations with non-EU countries. But the downside to being outside the Customs Union is that exports from EEA members to the EU must satisfy rules of origin requirements to enter the EU tariff free. This increases the cost of trade, especially in industries with complex global supply chains such as the automotive industry. The EU can also use anti-dumping measures to restrict imports from EEA countries, as occurred in 2006 when the EU imposed a 16% tariff on imports of Norwegian salmon. Campos, Coricelli, and Moretti (2015) find that Norway's failure to join the EU's Customs Union and undertake the deeper integration pursued by EU countries has lowered Norway's productivity.

Staying in the Single Market after Brexit is the option that would lead to the smallest increase

in UK-EU trade costs and our analysis below shows it is the least bad option for the UK economy. However, the UK government views EEA membership as having important drawbacks because it would not allow the UK to place restrictions on immigration from the EU and would mean the UK having to accept and implement EU economic legislation governing the Single Market without having any part in deciding the legislation ("Pay with no Say"). Currently, the UK government has announced it plans to leave the Single Market following Brexit.

2.2 Bilateral Trade Agreements

The second alternative is for the UK and the EU to negotiate a bespoke economic integration agreement. There are many forms such an agreement could take offering different degrees of economic integration. A basic free trade agreement (FTA) would remove almost all tariffs on goods trade, but would not provide for free movement of people or free trade in services between the UK and the EU. It would also lead to higher non-tariff barriers to UK-EU goods trade due to the introduction of border measures such as customs procedures and rules of origin requirements and the emergence of "behind-the-border" trade costs as UK and EU economic regulations diverged over time.

Most recent FTAs such as the Canada-EU FTA go beyond simply removing tariffs and also include provisions to increase market access in services and reduce non-tariff barriers. However, a FTA would not provide the same level of market access as membership of the Single Market. For example, no country that is not a member of the EEA has passporting rights for financial services or the same degree of regulatory harmonisation with the EU as exists within the Single Market. The UK government has signalled it plans to seek a FTA with the EU following Brexit, but as yet there is little clarity about what any agreement may cover.

Switzerland has a closer economic relationship with the EU than any other country outside the EEA. This relationship is based upon a series of bilateral treaties governing Swiss-EU relations. Usually, each treaty provides for Switzerland to participate in a particular EU policy or programme. For example, among many others, there are treaties covering insurance, air traffic, pensions and fraud prevention. Switzerland has achieved a similar level of goods market integration with the EU as EEA countries and there is free movement of people between Switzerland and the EU, but Switzerland and the EU have not reached a comprehensive agreement covering trade in services. Consequently, Switzerland is not part of the Single Market for services and Swiss financial institutions often serve the EU market through subsidiaries based in London.

The bilateral treaty approach allows Switzerland the flexibility to choose the EU initiatives

in which it wishes to participate, but does not allow Switzerland to influence the design of EU programmes. When Switzerland opts in to an EU programme it is required to implement policies and legislation set by the EU. Like the EEA countries, Switzerland makes a financial contribution to the EU to cover regional funding and the costs of the programmes in which it participates. Switzerland's contribution in recent years has averaged around £53 per capita, 60% lower than the UK's net contribution per capita (House of Commons, 2013).

Instead of negotiating a FTA with the EU, the UK could seek to remain part of the EU's Customs Union ensuring there would be no tariffs or other border costs on UK-EU goods trade. However, Customs Union membership would not guarantee market access for services trade or low behind-the-border non-tariff barriers since it would not prevent regulatory divergence. As a member of the Customs Union, the UK would also be subject to the EU's common trade policy, meaning it would not be able to negotiate its own FTAs with non-EU countries or set its own tariff rates.

2.3 Hard Brexit: WTO Terms

If the UK leaves the EU without reaching a new agreement with the EU then its trade with the EU and almost all the rest of the world would be governed by the WTO. Under WTO rules, each member must grant the same Most Favoured Nation (MFN) market access, including charging the same tariffs, to all other WTO members. The only exceptions to this principle are that countries can choose to enter into free trade agreements such as the EU Customs Union or NAFTA and can give preferential market access to developing countries.

As a WTO member, the UK's exports to the EU and other WTO members would be subject to the importing countries' MFN tariffs. This would raise the cost of trade between the UK and the EU. Non-tariff barriers between the UK and the EU would also increase as WTO rules provide for shallower integration than Single Market membership or a FTA. The UK's services trade would also be subject to WTO rules. Since the WTO has made far less progress than the EU in liberalising trade in services, this would mean reduced access to EU markets for UK service producers.

The WTO has no provisions for free movement of labour, so free labour mobility between the UK and the EU would cease. The pay-off for the lack of economic integration would be greater political sovereignty. Being outside the Single Market and not constrained by any bilateral agreement with the EU would enable the UK government to set economic policy and regulatory standards without taking account of the preferences of other EU members. However, any divergence in regulation

between the UK and the EU would increase non-tariff barriers to UK-EU trade.

Reverting to WTO trade relations is the alternative that would lead to the largest increase in trade costs between the UK and the EU. The UK government hopes to avoid this alternative, but has refused to rule out the possibility of trading with the EU on WTO terms if it is unable to achieve its objectives in negotiations over a new trade agreement with the EU.

3 Conceptual Framework

To estimate the effect of Brexit on the UK's trade and living standards, we use a modern quantitative trade model of the global economy (Ottaviano, 2014). Quantitative trade models incorporate the channels through which trade affects consumers, firms and workers, and provide a mapping from trade data to welfare. The model provides numbers for how much real incomes change under different trade policies, using readily available data on trade volumes and potential trade barriers. It allows for trade in both intermediate inputs and final output in both goods and services. The model takes into account the effects of Brexit on the UK's trade with the EU and the UK's trade with the rest of the world.

We build on Arkolakis, Costinot, and Rodriguez-Clare (2012) and Costinot and Rodríguez-Clare (2014), who show that some of the most popular models used by trade economists fall in a specific class sharing 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 trade in domestic expenditure and an estimate of the 'trade elasticity' (i.e. the elasticity of exports with respect to trade costs).[2] 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; and (C) the import demand system exhibits constant elasticity of substitution (CES). While this set of assumptions may look extremely restrictive, they are satisfied by several standard trade models including the workhorse 'Computable General Equilibrium' model by Armington (1969), the hallmark 'new trade theory' model by Krugman (1980), the quantitative Ricardian model by Eaton and Kortum (2002) and several variations of the heterogeneous firms model by Melitz (2003). Further, it is possible to relax some of the assumptions of the baseline model, for example by allowing for multiple factors

[2]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.

of production such as skilled and unskilled labour.

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 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 figure out how trade patterns and income will change, depending on the degree to which trade costs rise.

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 models such as the one we develop in this paper remain a cornerstone of trade policy evaluation (Piermartini and Teh, 2005), having also contributed to the design of advanced software for their numerical solution such as GAMS or GEMPACK (Harrison, Horridge, Pearson, and Wittwer, 2004). Compared to older Computable General Equilibrium trade models, 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 Rodríguez-Clare, 2014).

In what follows, we first explain the basic logic of our methodological approach through a simplified model. We then describe the additional elements of the richer model we actually use for simulation.

3.1 The Eaton-Kortum Model

For parsimony, we discuss only the main features of the model underlying our estimates. This is the most technical section of our paper, so readers who are more interested in the substantive results can skip to section 4. Additional details on the models and their empirical implementation can be found in Costinot and Rodríguez-Clare (2014).

Our simulations will be based on an extended version of the quantitative model of Eaton and Kortum (2002), as presented by Costinot and Rodríguez-Clare (2014), featuring multiple sectors and tradable intermediate inputs. Markets are assumed to be perfectly competitive and international trade is driven by cost differences across countries mediated by geographical distance and trade barriers. We make the conservative choice of focusing on the case of perfect competition, which provides a *lower bound* to the welfare effects of changes in trade barriers in models based on Costinot

and Rodríguez-Clare (2014).[3]

3.2 How It Works

To explain the logic of our model we use a simplified one-sector version with only final goods and no tariff revenues. Consider n countries, indexed by $j = 1, ..., n$, trading with one another. In country j there are L_j identical households, each supplying one unit of labour inelastically at salary w_j. The level of welfare of the representative household in country j is measured in terms of real consumption c_j, defined as household expenditure e_j divided by the country's price index P_j:

$$c_j = \frac{e_j}{P_j}.$$

The price index is computed over a basket of goods that may be produced domestically or imported from other countries. The weight of each country in country j's basket of goods depends on how cost-effective this country is as a producer relative to other countries, and how accessible this country is in terms of geographical proximity and other trade barriers. Specifically, if we use $E_j = e_j L_j$ to denote country j's aggregate expenditures and X_{ij} its expenditures on goods produced by country i, the share of aggregate expenditures going to these goods is given by $\lambda_{ij} = X_{ij}/E_j = \Phi_{ij}/\Phi_j$ with $\Phi_{ij} = H_i \left(w_i d_{ij}\right)^{-\theta}$ and $\Phi_j = \sum_{i=1}^{n} \Phi_{ij}$. The bundling parameter Φ_{ij} measures country i's effectiveness in supplying country j, taking into account its state of technology H_i, its wage w_i as well as the bilateral trade obstacles d_{ij} between the two countries due to geography and other barriers. The fact that Φ_{ij} is divided by $\Phi_j = \sum_{i=1}^{n} \Phi_{ij}$ signals that what determines the share of country j's expenditures allocated to goods from country i depends on the latter's effectiveness in supplying the former relative to all trade partners. This generates the 'gravity equation'

$$X_{ij} = \frac{\Phi_{ij}}{\Phi_j} E_j = H_i \left(w_i\right)^{-\theta} \left(d_{ij}\right)^{-\theta} \frac{E_j}{\Phi_j}, \tag{1}$$

i.e. a log-linear relation explaining exports from i to j in terms of characteristics of the exporter (H_i and w_i), characteristics of the importer (E_j and Φ_j) and bilateral trade obstacles (d_{ij}). This relation shows that bilateral exports are promoted by better exporter state of technology (larger H_i) and higher importer income (larger E_j). Bilateral exports are hampered by higher exporter wage (larger w_i) and greater importer proximity to trading partners (larger Φ_j) as this gives the

[3] In models of monopolistic competition,Dhingra and Morrow (2012) show that CES demand, that we use in this paper, provides a lower bound for the gains from international integration.

importer more options in terms of suppliers different from i that are easy to source from. Bilateral exports are also hampered by higher bilateral trade obstacles (larger d_{ij}) with a percentage point increase in d_{ij} leading to a θ percent fall in X_{ij}. The parameter θ thus measures the elasticity of bilateral exports to bilateral trade obstacles. It is usually referred to as the trade elasticity and is a crucial parameter for us as it will regulate the impact of Brexit-driven changes in trade barriers on UK income through the implied changes in trade flows.

As all markets are assumed to be perfectly competitive, there are no profits so that expenditures coincide with labour income: $e_j = w_j$ and $E_j = w_j L_j$. Moreover, all goods are priced at the marginal cost of delivering one unit to the destination. The price index in country j is determined by the (geometric) average of the delivered prices of all goods as

$$P_j = \gamma \left(\Phi_j\right)^{-\frac{1}{\theta}},$$

where γ is a constant. The equilibrium of the model is determined by the aggregate budget constraints of the n countries, which ensure that bilateral trade is balanced for all country pairs or, equivalently, that a country's income is equal to what all countries (including itself) spend on the goods it produces: $E_j = \sum_{i=1}^{n} X_{ji}$. Using the gravity equation (1) and $E_j = w_j L_j$ to substitute for X_{ji} and E_j respectively, we then have:

$$w_j L_j = \sum_{i=1}^{n} \frac{\Phi_{ji}}{\Phi_i} w_i L_i, \tag{2}$$

for each country $j = 1, .., n$. This defines a system of n non-linear equations in the n unknown wages. This non-linearity is due to the fact that Φ_{ji}, and thus Φ_i, are non-linear functions of wages and means that an analytical solution is not possible.[4] Hence, we solve for equilibrium wages using numerical methods and then finally compute real consumption per household

$$c_j = \frac{w_j}{\gamma \left(\Phi_j\right)^{-\frac{1}{\theta}}}. \tag{3}$$

This is our welfare measure and, given that labour is the only source of income, it coincides with real income per household. In equilibrium, this will be higher in countries with a better state of technology and better connections to other countries with a good state of technology. It is

[4]Note that, as balanced budget for $n-1$ countries implies balanced budget also for the remaining country, one of the aggregate budget constraints is redundant. The wage of one of the countries has, therefore, to be taken as the numeraire and the equilibrium values of all other wages will be expressed relative to that wage.

decreasing in the trade elasticity as the gravity equation (1) implies that larger θ amplifies the reduction in trade flows associated with higher wages and higher trade obstacles.

3.3 Calibration and Simulation

By fitting the model to observed patterns in the data, its fundamental parameters can be structurally estimated ('calibrated'). This fit will be conditional on the actual matrix of bilateral trade obstacles $[d_{ij}]_{i,j=1,..,n}$. We can then use the model with its estimated parameters to compute ('simulate') what would happen to its endogenous variables if the actual matrix $[d_{ij}]_{i,j=1,..,n}$ were replaced by any counterfactual matrix $[d'_{ij}]_{i,j=1,..,n}$ with changes in welfare measured by changes in real consumption per capita $\widehat{c}_j = c'_j/c_j$ where c'_j refers to the level of per-capita consumption when the matrix is $[d'_{ij}]_{i,j=1,..,n}$.[5]

The single-sector model with no intermediates and no tariff revenues has been useful to explain the mechanics of our methodology. To make the ensuing analysis more realistic, we will simulate an extended version featuring multiple sectors, intermediates and revenue generating ad-valorem tariff barriers. In this extension, each sector employs not only labour but also its own and other sectors' goods as intermediate inputs (with weights determined by country-specific input-output tables) and the representative household consumes a Cobb-Douglas basket of the goods supplied by the different sectors, indexed $s = 1, ..., S$. The change in welfare when moving to each counterfactual scenario compared to staying in the EU can be written as:

$$\widehat{c}_j = \frac{1-\pi_j}{1-\pi'_j} \prod_{s,k=1}^{S} \left(\widehat{\lambda}_{jj,k}\right)^{-\frac{\beta_{j,s}\widetilde{a}_{j,sk}}{\varepsilon_k}}, \tag{4}$$

where $\lambda_{jj,s} = X_{jj,s}/E_{js}$ is the share of country j's expenditures in sector s going to domestically supplied goods, π_j and π'_j are the shares of tariff revenue in country j's aggregate expenditures in the two scenarios, $\beta_{j,s}$ is sector s's share of household expenditures (with $0 < \beta_{j,s} < 1$ and $\sum_{s=0}^{S} \beta_{j,s} = 1$), $\widetilde{a}_{j,sk}$ is the elasticity of the price index in sector s with respect to changes in the price of sector k. The price elasticities are given by the elements of the $S \times S$ Leontief inverse matrix $(I - A_j)^{-1}$ where A_j is the matrix with typical element $\alpha_{j,sk}$ (with $0 < \alpha_{j,sk} < 1$) denoting the share of sector k's output in sector s's expenditure on intermediates.

[5] Given that we are interested in percentage changes, we do not need to estimate all the fundamental parameters of the model as several cancel out in log-differences. See Costinot and Rodríguez-Clare (2014) for additional details.

3.4 Brexit and Welfare

To estimate the welfare effects of Brexit we want to take into account not only its instantaneous effects, but also how Brexit will affect future consumption levels as trade costs change over time. This forward-looking perspective introduces two additional layers of complexity. First, we need to evaluate the present value of future real consumption flows. To do so, as in Caliendo, Dvorkin, and Parro (2015) we assume that the representative household in country j has an infinite horizon with time discount factor $\rho \in (0,1)$, and constant unit elasticity of intertemporal substitution so that its intertemporal welfare can be expressed as $\sum_{t=0}^{\infty} \rho^t \ln c_{j,t}$ where $c_{j,t}$ is real consumption in year t and $t = 0$ is the year in which Brexit takes place.

The second layer of complexity comes from the fact that the future consumption effects of Brexit need to be compared to what consumption would have been had the UK remained in the EU. This implies that we have to compare the present value of future consumption between two counterfactuals: remain ('In') and leave ('Out'). Following Sampson (2016), we measure the welfare effect of Brexit δ_j^{Brexit} in equivalent variation terms as the permanent proportional change in the level of consumption in the In scenario that would make the representative household in country j indifferent between the In and Out scenarios. This can be expressed as

$$\ln \delta_j^{Brexit} = (1-\rho) \sum_{t=0}^{\infty} \rho^t \left(\ln \widehat{c}_{j,t}^{Out} - \ln \widehat{c}_{j,t}^{In} \right), \tag{5}$$

where $\widehat{c}_{j,t}^{In} = c_{j,t}^{In}/c_{j,0}$ and $\widehat{c}_{j,t}^{Out} = c_{j,t}^{Out}(1+g_j)/c_{j,0}$ are the changes in real consumption in period t compared to period 0 for country j if the UK remains and after the UK leaves, respectively. To account for changes in fiscal transfers between the UK and the EU, the real consumption in the case of Out is multiplied by $1+g_j$ where g_j is the percentage change in the net fiscal transfer received by country j after Brexit. For example, if the UK made a lower transfer to the EU after Brexit, g_j would be positive for the UK while for the remaining EU countries it would be negative since they would need to fill the budget hole left by the lower UK contribution.

3.5 Model Summary and Intuition

Although our apparatus can appear complex at first sight, at heart it is very simple. Consider equation (2) as the central relationship we exploit to figure out the implications of Brexit. For each country we want to measure real labour income changes $\widehat{w_j/P_j} = (w_j'/P_j')/(w_j/P_j)$ as trade barriers rise after Brexit. We will have different scenarios (i.e. an optimistic soft Brexit and a

pessimistic hard Brexit) associated with different changes in trade barriers $\widehat{d}_{ij,s} = d'_{ij,s}/d_{ij,s}$. We also have data on the initial labour income w_j and expenditure shares $\lambda_{jj,s}$ of each country, and estimates of the trade elasticity θ from the literature on gravity equations. So basically we find the pattern of income changes that are consistent with the new set of bilateral trade barriers given the initial levels of trade and how sensitive these patterns are to price changes.

We can also think of this from a single country's perspective. When trade barriers 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 labour income (and this will have knock-on effects to other countries even if trade barriers 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.

4 Brexit Estimates from the Static Trade Model

In this section we use the quantitative trade model discussed above to estimate the welfare costs of Brexit in our optimistic and pessimistic scenarios. We start by describing the data we use to calibrate the model, then explain our assumptions regarding how trade costs change in each scenario before reporting our quantitative results.

4.1 Data

To calibrate the model we use the World Input-Output Database (WIOD) for 2011.[6] 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 Rodríguez-Clare (2014). Table 1 presents the UK trade pattern by sectors from the WIOD data (Table A.1 shows the regional aggregation).

The table splits the sectors between Goods and Services and trade with EU and non-EU countries. Overall, the UK runs a deficit in Goods trade but has surplus in Services. About 50% of UK trade in Goods and Services is with the EU in 2011. Trade between the UK and the EU is highest in the Transport Equipment sector, that includes automobiles, amounting to US$95.7 billion in 2011. The UK runs a deficit with the EU in this sector, with imports of US$60.4 billion compared to exports of US$35.3 billion. Within services, Renting of Machinery, Equipment and Other Business Services, and Financial Intermediation account for more than two-thirds of the UK's services trade with the EU. Overall, the UK has a goods trade deficit and a services trade surplus with the EU.

[6]The data can be found at http://www.wiod.org/database/wiots13. For more details on how this database is constructed, see Dietzenbacher, Los, Stehrer, Timmer, and de Vries (2013).

We also use data on the EU's applied MFN tariffs at the product level from the WTO.[7] Combining the tariff data with United Nations (UN) Comtrade data on trade flows allows us to calculate average MFN tariffs at the WIOD sector level for UK imports and exports with the EU using product level import and export values as weights.[8] The resulting average MFN tariffs on UK trade with the EU are shown in columns (4) and (7) in Table 1.

Finally, for trade elasticities which govern the responsiveness of trade flow to trade costs, we use the estimates by Caliendo and Parro (2015) in which they explore tariff variations to estimate trade elasticities for various goods sectors. As for the service sectors, the trade elasticities are set to be 5, the median value in the literature, following Costinot and Rodríguez-Clare (2014). These are listed in Table A.3.

4.2 Counterfactual Scenarios

This section describes the assumptions we make regarding changes in trade costs in our optimistic soft Brexit scenario and pessimistic hard Brexit scenario. We aim to quantify the consequences of three distinct types of trade costs: (i) immediate changes in goods tariffs; (ii) immediate changes in non-tariff barriers on goods and services; and (iii) the exclusion of the UK from future market integration within the EU.

We consider two different scenarios. In the pessimistic hard Brexit case we assume the UK leaves the Single Market and trades with the EU under WTO terms. In this case, we assume the UK will apply the MFN tariffs on goods imported from the EU shown in column (4) of Table 1, while the EU will apply the tariffs given in column (7) on its imports from the UK. In our optimistic soft Brexit scenario the UK remains part of the Single Market and there are no tariffs on goods trade between the UK and the EU.

Non-tariff barriers are related to costs of shipment, differences in product regulations, legal barriers, search and other transaction costs for both goods and services (see Anderson and van Wincoop, 2004; Head and Mayer, 2013). Many authors point out that such costs are higher than formal tariffs (Novy, 2013; LooiKee, Nicita, and Olarreaga, 2009). In fact, the primary focus of most recent trade negotiations, such as the Canada-EU free trade agreement, has been on reducing non-tariff barriers.

To incorporate non-tariff barriers we use information provided by Berden, Francois, Tamminen,

[7] We access the data from http://tariffdata.wto.org/ in 2014.

[8] We aggregate HS 6-digit industries into 2-digit WIOD industries using a concordance between HS products and ISIC Rev. 3 industries. The concordance is from http://wits.worldbank.org/product_concordance.html.

Thelle, and Wymenga (2009, 2013). The authors calculate detailed tariff equivalents of non-tariff barriers between the *US* 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 1. The sectors used, their non-tariff barriers (in tariff equivalent terms) and the share of the costs that can be reduced are shown in Table 2.

As it is unlikely the UK will face the same non-tariff barriers as the US following Brexit, in our optimistic scenario we assume the UK faces one-quarter (1/4) of the reducible non-tariff barriers faced by the US, while in our pessimistic scenario we assume UK-EU trade is subject to three-quarters (3/4) of the reducible non-tariff barriers. To implement these assumptions, we calculate the weighted average of the sectoral reducible non-tariff barriers using total UK-EU trade in each sector as weights and the subset of sectors shown in Table 2, which cover 71% of total UK-EU trade. This calculation leads to an increase in non-tariff costs of 2.77% and 8.31% in our optimistic and pessimistic scenarios, respectively. In our counterfactual simulations we apply these increases uniformly to UK-EU trade in *all sectors* of the economy.

Our counterfactuals also account for the observation that intra-EU trade costs are falling over time (Ilzkovitz, Dierx, Kovacs, and Sousa, 2007). The rate of decline in intra-EU trade costs is approximately 40% faster than trade costs between other OECD countries according to Méjean and Schwellnus (2009), who use panel data on French firms to study price convergence in different markets between 1995 and 2004.[9] To capture the consequences of this observation, we assume that following Brexit intra-EU trade costs will continue to decline, but UK-EU trade costs will not. In our pessimistic scenario we assume that intra-EU non-tariff barriers continue to fall 40% faster than in the rest of the world. This may not necessarily be the case since the OECD does not include countries like China, which has seen a rapid decrease in trade costs with other countries. Hence, in our optimistic scenario we assume that intra-EU barriers fall only 20% faster than in the rest of the world.

To implement these assumptions we need a measure of price differences across the EU. We use a rough measure of 49% taken from Eaton and Kortum (2002),[10] meaning that if the UK imported traded all goods with other European countries, prices would be 49% higher. Naturally, part of

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

[10] See their Table II, UK row average of the trade cost values.

this price difference may not be reducible. We assume that the reducible proportion is 54%, which is the average share of non-tariff barriers that are reducible in the EU-US trade case, as reported in Table 2. To be conservative, in our pessimistic case we further assume that only three-quarters of the potentially reducible share will actually diminish over time, while in the optimistic case we assume that the share is one-half. Finally, to be even more conservative, we assume that the faster intra-EU market integration will only last for 10 years after Brexit. These assumptions collectively imply that future declines in intra-EU trade costs will reduce non-tariff barriers within EU 10 years after Brexit by 12.65% and 5.63% in our pessimistic and optimistic scenarios, respectively.[11]

Finally, to incorporate the fiscal effects, we need to know the fiscal savings for each country under different scenarios. HM Treasury (2013) estimates that the net fiscal contribution of the UK to the EU is around 0.53% (or £8.6 billion) of UK GDP in 2013. We assume that if the UK stays in the Single Market it would keep contributing 83% of its current per capita payments to the EU, as Norway presently does (House of Commons, 2013). This leads to a fiscal saving of about 0.09% of GDP in the optimistic scenario. We also assume that the remaining EU countries need to fill this budget hole and that costs are allocated proportionally to each country's GDP. This leads to a fiscal loss of 0.015% of income for other EU countries. In the pessimistic case, we assume that the UK makes a fiscal saving of 0.31%.[12] Filling this budget hole leads to a fiscal loss of 0.051% for the remaining EU countries.

Armed with these numbers, we simulate the model by feeding in the sequence of shocks in trade costs and tariffs under our optimistic and pessimistic scenarios. The model then generates sequences of changes in real consumption. This allows us to compute the welfare effect of Brexit using equation (5). We assume that the discount rate of future consumption is $\rho = 0.96$, which is a standard value used in the calibration of growth models.

4.3 Main Results

Our key results are shown in Table 3. Panel A shows the result of the optimistic scenario. We find that the welfare loss[13] of the UK in the optimistic case is 1.34%. We also calculate the implied loss

[11] Appendix B provides a complete description of how these numbers are calculated.

[12] The 0.53% saving does not account for the transfers the EU makes directly to universities, firms and other non-governmental bodies in the UK. Under the reasonable assumption that post-Brexit the UK government does not cut this funding, the saving is 0.31% according to Eurostat(http://ec.europa.eu/budget/figures/2007-2013/index_en.cfm).

[13] Remember that welfare is measured as the permanent proportional change in the level of consumption in the *In scenario* that would make the representative household indifferent between the *In* and *Out* scenarios (for more details see subsection 3.4).

per household. In 2015 the UK had a population of about 65 million with 27 million households and a GDP of £1.8 trillion. 1.34% of 1800/27 is a loss of £893 per household. Panel B of Table 3 shows the result of the pessimistic scenario. We see that the cost of withdrawal doubles. The UK loses 2.66% due to higher tariffs, non-tariff barriers and exclusion from future integration of the EU. This is equivalent to £1,773 per household.

To better understand what is behind the welfare numbers in Table 3, we perform a slightly different exercise. Instead of running a single counterfactual including all the tariff and non-tariff barrier changes, we split each scenario into three parts, each one focusing on a different source of variation in trade costs and excluding changes in fiscal transfers. The results are shown in Table 4. In both scenarios the greatest welfare losses are due to exclusion from future EU integration: -0.90% and -1.61% in the optimistic and pessimistic scenarios, respectively. An increase in UK-EU non-tariff barriers also produces considerable welfare losses of -0.53% and -1.31% in the two cases.[14] In the optimistic case there are no tariff barriers to consider, while in the pessimistic case the introduction of tariffs imposes a small welfare reduction of -0.13% on the UK.

We also estimate the effect of Brexit on the welfare of other countries. The results are shown in Figure 1.[15] In both scenarios the UK experiences the largest welfare losses, but two types of countries other than the UK have relatively greater welfare losses. First, countries for which UK is an important trade partner, such as Ireland, Netherlands, Belgium, Denmark, Sweden, and Germany. These countries source more inputs from the UK, as can be seen in Figure 2, which shows the average share (across sectors) of inputs sourced from the UK by country. Ireland, for example, experiences the highest welfare loss and has the highest expenditure share of intermediate inputs coming from the UK.

A second group of countries that lose relatively more are those that do not trade much with the UK, but exhibit a negative cross-sectoral correlation between the expenditure share on intermediates sourced from the UK and the trade elasticity. Figure 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 the EU tend to gain from Brexit, although the numbers are very close

[14] If we assume that the post-Brexit NTBs between the UK and the EU would be equal to the full reducible US-EU amount, the welfare loss would be approximately 1.6%.

[15] See Table A.1 for more details on how countries are aggregated in the figure.

to zero. This is because of trade diversion effects 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 the UK). This is shown in Table 5. However, the gain experienced by non-EU countries is much smaller than the loss of the UK and the EU, as evident in Table 6. And the loss of the UK is more than the total loss of other EU countries, both in percentage terms and absolute terms.

5 Static Trade Model: Robustness Checks

In this section we assess the sensitivity of our welfare estimates for the UK to alternative assumptions concerning how Brexit will affect trade costs. In all the scenarios we consider Brexit makes the UK worse off, with welfare losses ranging between 1% and 4%. Our findings imply that the average UK household will certainly be poorer after Brexit, the only question is exactly how much poorer they will be.

5.1 Switzerland Option

The first alternative scenario we consider is what happens if the UK and EU negotiate a deal similar to the agreements between Switzerland and the EU described in Section 2.2. Such a deal would effectively allow the UK to remain part of the Single Market for goods, but not for services. Consequently, we assume that the Swiss option implies no tariffs on UK-EU trade and that (current and future) non-tariff barriers in goods increase by the same amount as in the optimistic soft Brexit case, while non-tariff barriers in services increase by the same amount as in the pessimistic hard Brexit case. We also assume the UK's net fiscal contribution to the EU budget declines by 60% reflecting the lower payments made by Switzerland.

The results are shown in Panel A of Table 7. We find that the Swiss option leads to a welfare loss of 1.44%, slightly higher than the loss in the optimistic scenario. Compared to the Norway option, the benefit of the Swiss option is lower fiscal transfers to the EU, but this is more than offset by the costs of higher non-tariff barriers for services.

5.2 Big Bang

Our next alternative is a "Big Bang" scenario with very large increases in trade costs following Brexit. In this case, we assume MFN tariffs are imposed on UK-EU trade as in the pessimistic scenario. We also assume non-tariff barriers between the UK and the EU would rise to the full

reducible level between the US and the EU, implying an immediate increase in non-tariff barriers of 11.08%. Finally, we assume integration within the EU would continue to be 40% faster than in the rest of the world and 100% of the reducible price gaps would be reduced. Such integration happens right during the year of Brexit instead of taking 10 years which we assume for the optimistic and pessimistic cases. It leads to a reduction of non-tariff barriers among EU countries by 15.72%. These extreme assumptions imply that we are simulating the upper bound of welfare loss for the UK in our model. In this scenario we find that the UK welfare loss is 3.84%.

5.3 Unilateral Liberalisation

Supporters of Brexit, such as the group Economists for Brexit, have argued that after leaving the EU the UK should unilaterally liberalise trade by removing all tariffs on its trade with the rest of the world (Economists for Brexit, 2016). We evaluate the consequences of this policy by simulating the effects of unilateral liberalisation in our optimistic and pessimistic scenarios.

We measure current sectoral tariff levels as the weighted average MFN applied tariff on HS 6-digit level UK imports from non-EU countries. As shown in Table A.2 the average UK MFN import tariff is just below 3%. Feeding these tariffs into our model we find the effect of unilateral liberalisation is very limited as shown in Panel B of Table 7. In both the optimistic and pessimistic cases unilateral liberalisation increases welfare by around 0.3% compared to our baseline results, implying that the overall welfare effect of Brexit including unilateral liberalisation is a loss of 1.05% in the optimistic case and 2.34% in the pessimistic case. The relatively small effect of unilateral liberalisation is not surprising given that the UK's import tariffs are already low and that we showed in Table 4 the main costs of Brexit result from higher non-tariff barriers.[16]

5.4 Discount Rate

In Panel C of Table 7 we report the welfare effects of Brexit under alternative assumptions about the discount rate ρ. So far, we have used a discount rate of 0.96 which implies a real interest rate of 4%. This is a standard calibration value, but currently real interest rates are much lower than this, near zero in many cases. Using a lower real interest rate increases the costs of Brexit, because it gives larger weights to future declines in consumption. For example, using a real interest rate

[16] According to our model the optimal unilateral tariff for the UK to impose on imports following Brexit would be around 15% (assuming a uniform tariff across all goods). Combining Brexit with this tariff policy implies UK welfare falls by 0.4% in the optimistic case and 1.8% in the pessimistic case. Thus, the UK still ends up worse off even before we account for retaliatory tariff changes by other countries.

of 1% by setting $\rho = 0.99$ leads to a welfare loss of 1.47% in the optimistic case and 2.91% in the pessimistic case. Hence, given the current low interest rate environment, the results we present in Table 3 may understate the true costs of Brexit.

5.5 Financial Services and Passporting Rights

Another concern is that Brexit could pose special challenges for the financial sector in the UK. The financial services sector makes up 8% of British GDP, 12% of tax receipts and 45% of the FDI stock (Tyler, 2015). The Single Market allows a bank based in one member of the EU to set up a branch or provide cross-border financial services in another, while being regulated by authorities in the home country. This 'single passport' to conduct activities in EU member states is important for UK exports of financial services. Passporting means that a UK bank can provide services across the EU from its UK base. It also means that a Swiss or an American bank can do the same from a branch or subsidiary established in the UK.

If the UK leaves the Single Market it will lose passporting rights. Alternatives to passporting rights are likely to be costly and time-consuming, because they would require either setting up subsidiaries within the Single Market or negotiating a regulatory equivalence agreement with the EU under which the EU could grant licenses to UK-based financial institutions to serve the EU market. However, these licenses would probably provide more restricted access to EU markets than passporting rights and could be withdrawn unilaterally by the EU. The UK will also lose the ability to challenge new regulations at the European Court of Justice (ECJ), a right that it successfully exercised when the EU wanted to limit clearing-house activities to the Euro area.

All these changes are likely to raise the cost of UK-EU financial services trade following Brexit, but are inadequately captured by our quantitative trade model. The financial sector also relies heavily on foreign investment which is not included in our model. This suggests the way we model financial services may lead us to underestimate the costs of Brexit.

5.6 New Free Trade Agreements with non-EU countries

Members of the EU have a common trade policy and are represented by the EU in all international trade negotiations. If the UK leaves the EU's Customs Union, Brexit could also lead to changes to the UK's trade relations with non-EU countries. This could lead to higher trade costs if the UK ceases to be a party to trade agreements it currently belongs to through its membership of the EU, such as the EU-Turkey Customs Union or the EU-South Korea FTA. Or it could increase

trade if the UK reaches new agreements with countries such as the US, China and India that do not currently have a trade agreement with the EU.

When negotiating post-Brexit trade deals, the UK would not need to compromise with other EU countries as it does now. However, because the UK's GDP is less than one-fifth of the EU Single Market's GDP, it would also have less bargaining power in trade negotiations than the EU currently does.

The key question is whether the UK would be able to obtain better market access to non-EU countries on its own than it would as a member of the EU. In calculating our quantitative estimates we have assumed leaving the EU does not affect trade costs between the UK and the rest of the world. However, if Brexit leads to a deterioration in the UK's access to non-EU markets then our estimates will understate the costs of Brexit. By contrast, if the UK is able to strike better trade deals than the EU then we are over-estimating the costs of Brexit.

Given the reduction in the UK's negotiating power post Brexit, our sense is that the UK's preferential access to non-EU markets is likely to be worse rather than better after it leaves the EU. In any case, since the EU is by far the UK's largest trade partner, it is highly unlikely any positive effects could be large enough to offset the welfare losses we estimate will result from higher trade costs with the EU.

6 Dynamic Brexit Effects

6.1 Dynamic Effects of Trade

In our static quantitative analysis we assume each country's underlying technological capability in each sector H_{is} is exogenous and remains constant over time. However, by increasing competition, raising R&D and facilitating the diffusion of ideas within and across countries trade integration can also lead to improvements in technology that raise the gains from trade (Buera and Oberfield, 2016; Desmet, Nagy, and Rossi-Hansberg, 2016; Perla, Tonetti, and Waugh, 2015; Sampson, 2016). For example, Sampson (2016) shows that in a dynamic version of the Melitz (2003) model lower trade costs increase the long-run growth rate generating dynamic welfare gains that roughly triple the gains from trade compared to conventional static estimates. Bloom, Romer, Terry, and Van Reenen (2014) also find that dynamic effects may double or triple the gains from trade.

The dynamic gains from trade are less well understood than the static gains captured by our model. More empirical work is needed to establish the relative importance of the different channels

studied in the theoretical literature and to allow for the development of a workhorse quantitative trade model that incorporates dynamic technology effects. However, the existing literature suggests that dynamic effects are quantitatively important and that static models substantially underestimate the gains from trade. This implies that by using a static trade model we underestimate the costs of Brexit. The true costs could easily be triple our reported estimates.

6.2 Reduced Form Brexit Estimates

To obtain estimates of the consequences of Brexit that incorporate dynamic effects we adopt an approach that uses existing empirical estimates of the effects of EU membership to infer the impact of leaving the EU on UK income per capita. In particular, we can decompose the question into two parts. First, what effect will leaving the EU have on the UK's trade with other countries? Second, what is the effect of changes in trade levels on income per capita? To answer these questions we can use estimates drawn from the 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 per capita.

Suppose that after leaving the EU the UK negotiates a free trade agreement with the EU that is similar in scope to the European Free Trade Association (or simply EFTA).[17] How would this affect the UK's trade with other EU members? Baier, Bergstrand, Egger, and McLaughlin (2008) address exactly this question by estimating a gravity model of bilateral goods trade augmented with dummy variables capturing which EIAs the exporter and importer belong to. In particular, they include dummy variables for both countries belonging to 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. They try to control for endogenous selection into the formation of EIAs by estimating the model with panel data and controlling for country-pair fixed effects meaning their estimates are identified from the variation in trade that occurs when countries join or leave EIAs. 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 leaving the EU and joining EFTA would reduce the UK's trade with EU members

[17]The EFTA has four members: Iceland, Liechtenstein, Norway, Switzerland. Iceland, Liechtenstein and Norway are also parties to the EEA Agreement with the EU.

by 25.2%.[18] Interestingly, the magnitude of the trade fall is similar to that implied by our static structural model in the long-run.

To estimate the change in the UK's overall trade we also need to know the effect of Brexit on the UK's trade with non-EU members. Baier, Bergstrand, Egger, and McLaughlin (2008)'s 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 offer mixed results, but fail to provide convincing evidence that joining an EIA usually leads to a reduction in trade with countries outside of the EIA. For example, Magee (2008) does not find robust evidence of significant trade diversion effects from EIAs. Therefore, while acknowledging that the trade diversion effects of EU membership are far from certain, we will proceed under the assumption 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 per capita we use the estimates of Feyrer (2009). Feyrer regresses income per capita on trade using changes in the cost of shipping goods via air relative to sea as an instrument for changes in trade. Since the instrument is time varying, Feyrer 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 country characteristics that are correlated with both trade openness and income levels. He finds that the elasticity of income to trade is probably between one-half and three-quarters. In other words, a 10% increase in trade raises income by 5% to 7.5%. Feyrer (2009)'s estimation strategy is likely to capture both the direct effect of trade on income per capita as well as other indirect income effects of increased proximity between countries, such as changes in FDI and knowledge diffusion. Thus, the estimates we obtain in this section should be interpreted as capturing some of the non-trade channels through which leaving the EU

[18] This figure is calculated using the estimates in their 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 $e^{0.19} - 1 = 21\%$. Therefore, if a country leaves the EU and joins EFTA trade with EU members declines by $(e^{0.48} - e^{0.19})/e^{0.48} = 25.2\%$. 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 belongs to 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.

will affect the UK in addition to the direct effect of changes in the UK's trade.[19]

Using these numbers we can obtain a reduced form estimate of the effect of leaving the EU and joining EFTA on UK income per capita. Since approximately half of the UK's trade is with the EU (Office for National Statistics, 2016), a 25.2% fall in trade with EU members would reduce the UK's overall trade by 12.6% if there was no change in trade with non-EU countries. Combining this decline with the estimates of Feyrer (2009) implies that leaving the EU and joining EFTA would reduce the UK's income per capita by between 6.3% and 9.4%. Interestingly, these estimates are similar to the findings of Crafts (2016) who, after surveying a range of papers that seek to estimate the historical consequences of EU membership, concludes that joining the EU increased UK GDP by around 8% to 10%.

The reduced form estimates calculated above are based on estimates of the impact of Brexit on the UK's trade with the EU. Ebell (2016), HM Treasury (2016) and Mulabdic, Osnago, and Ruta (2017) all find positive effects of EU membership on trade levels and although the size of the effects varies across papers it is generally larger than estimated by Baier, Bergstrand, Egger, and McLaughlin (2008).[20] For example, Mulabdic, Osnago, and Ruta (2017) estimate how Brexit will affect UK trade using a new database on the coverage of different trade agreements collected by Hofmann, Osnago, and Ruta (2017). They find that agreements with greater coverage generate more trade in both goods and services. The EU has the broadest coverage of all existing trade agreements meaning that any alternative agreement between the UK and the EU following Brexit is likely to reduce UK-EU trade. Their estimates imply that if the UK were to join the EEA, like Norway, UK-EU trade would fall by 13.1%, and if the UK and the EU were to negotiate an "average" free trade agreement trade would fall by 40.1% and if the UK and EU were to trade under WTO terms trade would fall by 53.3%.[21]

Under the assumptions that there is no trade diversion and the elasticity of income per capita to trade is between 0.5 and 0.75 as estimated by Feyrer (2009), these results imply the Norway option would reduce UK income per capita by between 3.3% and 4.9%, the FTA option would lead

[19] Feyrer (2011) estimates an elasticity of income per capita to trade of around 0.25 using the 1967-75 closure of the Suez canal as an instrument for changes in trade. This lower estimate is less likely to include indirect effects of greater proximity, but since the closure of the Suez canal was temporary it is less useful for our purposes because it does not represent the long-run effects of changes in trade.

[20] The estimated effect of EU membership on trade also varies across different specifications in Baier, Bergstrand, Egger, and McLaughlin (2008). Using the estimates in Table 5, column 1 implies leaving the EU and joining EFTA would reduce the UK's trade with EU members by $(e^{0.19} - e^{0.65})/e^{0.65} = 36.9\%$ which implies a decline in UK income per capita of between 9.2% and 13.8%. By using the estimates in Table 6, column 1 we obtain a more conservative estimate of the costs of Brexit.

[21] These numbers are calculated using the estimates in Table 6 of Mulabdic, Osnago, and Ruta (2017) together with the fact that in 2014 goods made up 72% UK-EU trade and services 28% (Office for National Statistics, 2016).

to a 10.2% to 15.3% decline and the WTO option would cut UK income per capita by between 13.3% and 20.0%. Although the magnitude of the losses varies considerably across scenarios it is clear that Brexit is likely to lead to a substantial decline in the UK's income per capita and, as our quantitative estimates also showed, remaining in the Single Market by joining the EEA would minimise the costs of Brexit, while reverting to WTO trade relations is the worst case scenario.[22]

The reduced form approach adopted in this section has two principal advantages over the structural approach used earlier in the paper. First, it requires less detailed assumptions about what happens to trade barriers between the UK and the EU following Brexit, since it does not require us to specify the future paths of tariffs and non-tariff barriers on UK-EU trade. Instead the reduced form estimates are based on simple assumptions about what type of post-Brexit relationship the UK and EU will negotiate. 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 per capita 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 of the effect of EU membership on trade and the effect of trade on income per capita. 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. Of course, the estimates could understate as well as overstate the magnitude. Overall, the calculations in this section could be viewed as a robustness check on the plausibility of the predictions obtained from the quantitative trade model. They suggest that the effects 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 net impact on UK welfare.

6.3 Foreign Direct Investment

Our quantitative model of sections 3 through 5 does not include FDI. This is one reason that explains why our reduced form estimates of the impact of Brexit on the UK economy are much larger than our estimates from the structural trade model. The UK is a major recipient of FDI with an estimated FDI stock of over £1 trillion, about half of which is from other members of

[22] When considering the reduced form and quantitative estimates note that the results are not directly comparable because the outcome variable differs slightly between the two alternatives. The reduced form approach estimates long-run changes in income per capita, while the quantitative estimates focus on changes in a consumption-equivalent measure of welfare. Our reduced form estimates also do not incorporate any changes in fiscal transfers between the UK and the EU.

the European Union (EU), according to UK Trade and Investment UKTI, 2015. Only the United States and China receive more FDI than the UK.

Countries generally welcome FDI as it tends to raise productivity, which increases output and wages. FDI brings direct benefits as foreign firms are typically more productive and pay higher wages than domestic firms. But FDI also brings indirect benefits as the new technological and managerial know-how in foreign firms can be adopted by domestic firms, often through multinationals' supply chain (Harrison and Rodríguez-Clare, 2010). FDI can also increase competitive pressure, which forces managers to improve their performance. Bloom, Sadun, and Van Reenen (2012) find that multinationals boost productivity in UK establishments through enhanced technologies and management practices. On top of this direct effect, Haskel, Pereira, and Slaughter (2007) find that there are foreign investment 'spillovers' to other, UK-owned firms in the same industry.

There are at least three reasons why FDI in the UK may fall following Brexit. First, being in the Single Market makes the UK an attractive export platform for multinationals as they do not bear potentially large costs from tariff and non-tariff barriers when exporting to the rest of the EU. Second, multinationals have complex supply chains and many co-ordination costs between their headquarters and local branches. These would become more difficult to manage if the UK left the Single Market. For example, component parts would be subject to different regulations and costs and intra-firm staff transfers would become more difficult with tougher migration controls. Third, uncertainty over future trade arrangements between the UK and the EU would also tend to dampen FDI.

To provide some evidence on how Brexit may affect FDI in the UK we next review empirical work that estimates the impact of EU membership on FDI. We first examine estimates of EU membership on country-level FDI flows and then discuss a sector-level study that uses very fine investment data to capture the various channels through which Brexit would impact car production in the UK.

6.3.1 Country-level FDI and Brexit

Using country-level bilateral FDI flows between 34 OECD countries from 1985 to 2013, Bruno, Campos, Estrin, and Tian (2016) estimate a gravity model of inward bilateral FDI flows. They model FDI between two countries as a function of their respective market sizes (measured by GDP), the geographical distance between them and other factors such as GDP per capita. The model addresses the question of how much more FDI would flow between two countries if the

sender or the recipient joins the EU, once all these factors are taken into account. Since many FDI determinants – such as geographical distance and culture – are broadly stable over time, they control for them by looking only at changes in FDI and its determinants.

The data show that there is always a statistically significant positive effect of being in the EU on inward FDI. The magnitude ranges from a 14% to 38% increase in FDI across specifications, with an average increase of 28% for the three main methods. This implies Brexit is likely to reduce future FDI inflows to the UK by about 22%.[23]

These estimates are consistent with those in Campos and Coricelli (2015), who find a positive impact of 25% to 30% on FDI flows from EU membership using an alternative method that compares the evolution of FDI in the UK with FDI in a set of matched control countries. Similarly, Straathof, Linders, Lejour, and Mohlmann (2008) find that EU membership increases inward FDI stocks by 14% from non-EU countries and by 28% from other EU members (using a gravity model but with earlier data). Being a member of EFTA like Switzerland does not seem to restore the FDI benefits of being in the EU. In fact, Bruno, Campos, Estrin, and Tian (2016) find no statistical difference between being in EFTA compared with being completely outside the EU like the US or Japan.

How would reduced FDI from exiting the EU affect UK incomes? To answer this question we can draw on the work of Alfaro, Chanda, Kalemli-Ozcan, and Sayek (2004) who estimate the effect of changes in FDI on growth rates across 73 countries. They find that increases in FDI have a large positive impact on GDP growth, especially for countries like the UK that have a highly developed financial sector. Dhingra, Ottaviano, Sampson, and Van Reenen (2016) take a very conservative approach and assume a scenario where the Brexit-induced fall in FDI lasts only for 10 years and then reverts to its current level. Using the average of the estimates for the FDI fall combined with Alfaro et al's estimates implies a fall in real income of about 3.4%. Looking at the wider range of estimates, incomes would fall by between 1.8% and 4.3%. The magnitude of our FDI effect on income, of 3.4%, is larger than our estimates of the losses from trade (between 1.3% and 2.7%). Using earlier data, Pain and Young (2004) find a similar estimate that EU membership added 2.25% to UK GDP via FDI. As FDI into the UK has grown over time, we find that this channel is becoming more important for income.

[23] Using a baseline estimate of 0.28, we obtain $0.22 = 0.28/(1+0.28)$. Our estimate is very similar to PWC (2016), which finds that UK FDI will be a quarter lower in 2020 because of Brexit.

6.3.2 Sector-level FDI flows and EU membership

The country-level analysis above is useful for a bird's-eye view of the impact of Brexit on national income via lower FDI. Firm-level studies will tend to underestimate the positive impact of FDI as they focus on the productivity of the foreign firm itself or can examine only a limited number of mechanisms for the FDI spillovers (for example, firms who are in the same industry as the multinational or are suppliers or customers). Nevertheless, identifying the causal effects of FDI on economy-wide productivity is intrinsically very difficult and our estimates are subject to considerably more uncertainty than the impact of Brexit on FDI (or trade) itself.

So, to obtain a more granular view, we discuss Head and Mayer (2015) which focuses on the car industry that has very rich data on the investment decisions of multinationals. The UK is the world's fourth largest producer and KPMG (2014) argues that 'much of the recent investment by car manufacturers is in new vehicles which will be predominantly for sale to the EU market.' To estimate how Brexit would impact the car industry in the UK, Head and Mayer model Brexit as an increase in the costs of shipping cars between the UK and the EU (due to non-tariff and possibly tariff barriers), and as an increase in the co-ordination costs between headquarters and the local production plants (due to migration controls that make transfer of key staff within the firm harder or due to different regulatory standards across plants).

Head and Mayer extend the structural gravity model of trade to the decisions of multinationals over where to base their production. Using information on the assembly and sales locations of 1,775 car models across 184 brands, they model how firms decide where to locate their production for each market – for example, why BMW chooses to produce Minis in the UK when selling to France. They estimate that total UK car production would fall by 12% or almost 180,000 cars per year if Brexit increases both trade costs and coordination costs. This is mainly because European car manufacturers such as BMW would move some production away from the UK. Prices faced by UK consumers would also rise by 2.55% as the cost of imported cars and their components increase. In a more optimistic scenario, Head and Mayer assume that the UK faces no trade barriers on cars and car components with the rest of the EU (for example, it joins EFTA and keeps equivalent regulations). When Brexit only increases headquarters co-ordination costs, total car production in the UK still falls by 2.4% and prices remain stable.

In short, the detailed model in Head and Mayer confirms the macroeconomic and survey evidence that Brexit will reduce foreign investment coming into the UK, leading to a fall in economic activity.

We therefore conclude that one of the reasons our reduced form estimates for the impact of Brexit on the UK economy are bigger than the estimates from the quantitative trade model is because they capture the channel of reduced investment, which is correlated with trade flows.

7 Distributional Effects

Our results imply Brexit is likely to have a negative aggregate effect on UK living standards. But changes in trade can also have distributional consequences and it is theoretically possible that some households could be unaffected, or even gain following Brexit. If EU membership has increased income and wealth inequality in the UK, then Brexit may benefit poorer households. We adopt several approaches to shed light on the distributional aspects of Brexit. First, we review the evidence on the effects of EU immigration on the UK economy, since it is often argued that immigration is one of the main channels through which EU membership has harmed low income UK households. Second, we extend our quantitative trade model to see how the implied price effects of Brexit affect households with different levels of income. Third, we discuss the potential effects of UK-EU trade on the wage distribution. All these approaches suggest that the costs of Brexit are likely to be shared rather evenly across income groups - there is certainly no evidence that the poor will in any way avoid the Brexit shock.

7.1 Immigration

Immigration was a major feature of the Brexit debate. Members of the Single Market must allow free movement of people with other members. The UK experienced a large increase in EU immigration after the accession of several Eastern European countries in 2004. Over the 1995 to 2015 period the number of EU nationals living in the UK more than tripled from 0.9 million to 3.3 million.

The UK labour market is the most lightly regulated in Europe according to OECD indicators and seemed to absorb the immigrant wave without obvious negative effects. In 2016 the employment rate of around 74% was a record high. Unlike the US median real wages grew at a healthy pace between 1979 and 2007, but fell by over 8% in the 6 years following the global financial crisis. Although this aggregate fall had little or nothing to do with EU immigration, which was rising in the years before the crisis and continued to rise after 2008, many people linked the two trends, blaming immigrants for falling pay.

Even if EU immigration had little effect on aggregate unemployment or wages, could it have had

effects on inequality? Compared to the British born, EU immigrants are better educated, which would suggest if anything they would put more downward pressure on higher wage workers.[24] There is a huge amount of research examining the effect of immigration on jobs and wages. The UK work is summarized in Wadsworth (2015) but see also Portes (2016), Centre for European Reform (2016) and Dustmann, Fabbri, and Preston (2005). The conclusion of this body of empirical research is that the large increase in EU immigration to the UK has not harmed the job and wage prospects of UK born workers. Most papers find zero effects on all groups of UK born workers, but even those papers uncovering significant negative or positive effects find that these are small in magnitude. The only case where some stronger negative effects have been identified is for the effects of immigrants on earlier waves of immigrants (see Manacorda, Manning, and Wadsworth, 2011).

Most of the work on immigration considered the period before the financial and Euro zone crisis, so it is possible that things have changed after 2008. To address this issue we aggregate individual data from the Labour Force Survey by area (201 local authorities) (see Wadsworth, Dhingra, Ottaviano, and Van Reenen, 2016, for more details). We form an area-level panel from 2008 and 2015 and examine correlations of the change in the stock of EU immigrants and changes in various labour market outcomes for UK born individuals.

Figure 4 considers changes in the unemployment rates of the UK born in relation to changes in EU immigration (one observation for each local authority). The solid line summarizes the relationship. If immigration increased unemployment, we would expect a strong upward sloping line: more EU immigrants would mean more unemployment for local workers. In fact, the line indicates that a 10 percentage point increase in the share of EU immigrants in a local area is associated with a 0.4 percentage point reduction in the unemployment rate in that area. But it is very clear from the graph that there is absolutely no statistically significant relationship (negative or positive) of EU immigration on unemployment rates of those born in the UK. The same lack of association is also revealed when we look at hourly wages of the UK born as an outcome and when we use the initial level of EU migrants in the local area as an instrumental variable for subsequent EU immigration.

For inequality we need to look at the labour market outcomes of the less skilled. Figure 5 implements the same approach as the previous figure but uses the wages of low educated workers as an outcome on the vertical axis. Again there is no relationship between the increase of EU

[24]EU immigrants are also younger, more likely to be in work and less likely to use welfare. Hence, as shown by Dustmann and Frattini (2014), they make a contribution to reducing the budget deficit.

immigration and average wages of the less skilled. The same is true for employment rates (see Wadsworth, Dhingra, Ottaviano, and Van Reenen, 2016).

This type of local area analysis misses out on nationwide general equilibrium effects. There is also work examining the macro-economic impact of immigration to the UK which tends to find positive general equilibrium effects on productivity (e.g. Boubtane, Dumont, and Rault, 2015; Ottaviano, Peri, and Wright, 2016). This implies reductions in immigration will add to the cost of Brexit.

Overall, our view is that there is overwhelming evidence immigration from the EU has not had strongly negative effects on the level or distribution of income in the UK.

7.2 Distributional Effects through Prices

To look at the effects on inequality of price changes following Brexit, we augment our static approach of sections 3 through 5 to allow for heterogeneity in the consumption bundles of different households (see Breinlich, Dhingra, Sampson, and Van Reenen, 2016, for more details of this exercise).

Since the model allows for 31 different industries, we can track for each of the counterfactual simulations the implied changes in prices at the industry level. These price changes will have different effects on individuals depending on their consumption bundles. Since the 31 sectors include business-to-business sales (intermediate inputs), which consumers do not directly purchase, we focus on final goods and service price changes.

Groups that consume a substantial share of tradable products are predicted to see the largest price increases. Prices would rise most for transport (4% optimistic to 7.5% pessimistic), alcohol (4% to 7%), food (3% to 5%) and clothing (2% to 4%). By contrast, service sectors such as education or hotels and restaurants would be less affected because they rely more on non-tradable local inputs.

Figure 6 shows welfare effects for ten income groups, from the poorest 10% to the richest 10% of household income using expenditure data from the ONS Living Costs and Food Survey 2012. There are substantial differences in how groups choose to spend their money as indicated by their expenditure shares across product groups. For example, the poorest 10% of households spend 16% of their income on Food and non-alcoholic drinks, whereas the richest 10% of households only spend around 8% on this category. This reflects the well-known fact that poorer consumers need to spend a larger proportion of their income on essentials. By contrast, low-income households spend only 7% on Transport, which includes the purchase of vehicles as well as transport services such as rail

and air travel; the richest 10% of households spend 16% of their income on transport.

Figure 6 summarises the effect of the price changes following Brexit on the real incomes of the different household groups. In both scenarios it seems that the drops are reasonably even across the income distribution with all deciles suffering significant losses. It is certainly not the richest 10% who do a lot worse. Households in the middle income groups are hit slightly harder than those at the extremes.

In summary, it seems that losses of real expenditure are shared relatively evenly across the income distribution. They are certainly not borne disproportionately by the rich. Moreover, recall that these calculations ignore any dynamic effects of Brexit which will increase the consumption losses across households of all types.

7.3 Distributional Effects through Wages

The calculations in the previous section focused on the distributional effects of Brexit resulting from variation in the composition of expenditure, assuming nominal wage changes are proportional across income groups. This seems to be a reasonable assumption. The changes in prices across sectors predicted by our model are only weakly correlated with average earnings across sectors (see Breinlich, Dhingra, Sampson, and Van Reenen, 2016). If anything, high-wage sectors are predicted to see larger price increases on average after Brexit, implying that the wages of the better paid may rise relative to the low-paid .

This is unsurprising. The EU is a relatively rich, highly skilled bloc much like the UK. Changing trade barriers with countries whose factor endowments are very different from the UK, like China[25] or India, could affect relative wages through Heckscher-Ohlin effects, but this channel is unlikely to be important for UK-EU trade (also see Helpman, 2016, for a recent assessment suggesting that the overall impact of trade on inequality is not quantitatively large).

Another approach to assessing the relative wage effects of Brexit is to build on Costinot and Rodríguez-Clare (2014) who extend the single factor production function used in our quantitative trade model to include both skilled and unskilled labour and show that for the US moving to autarky has basically no effect on wage inequality. Performing a similar calculation for the UK using our WIOD data shows that moving to autarky reduces the real wage of skilled workers by 22.9% and the real wage of unskilled workers by 21.3%. This suggests that changes in inequality

[25] Autor, Dorn, and Hanson (2016) suggest substantial negative effects on inequality due to China. Pessoa (2016) also finds earnings losses for less skilled worked, even though welfare as a whole rises from the China shock.

are an order of magnitude smaller than aggregate welfare changes.

7.4 Summary on Distributional Effects

In this section we have examined how the negative average impact of Brexit plays out across different points on the income distribution by analysing immigration, prices and wages. We find that the economic pain of Brexit is not just concentrated on the elites but democratically shared out across people of all household incomes.

8 Conclusions

This paper estimates how Brexit will affect the UK economy, focusing on the consequences of changes in trade and fiscal transfers between the UK and the EU. Using a standard quantitative trade model based on Costinot and Rodríguez-Clare (2014) we simulate the effects of Brexit under alternative counterfactual assumptions regarding the future of UK-EU trade relations. In our optimistic scenario, where the UK remains in the Single Market, Brexit reduces living standards in the UK by 1.3%. In our pessimistic scenario, where the UK and EU trade under WTO terms, the loss doubles to 2.7%.

It is likely that these static estimates understate the true costs of Brexit, as they do not account for the dynamic effects of trade on productivity or for the effects of Brexit on FDI and immigration. Employing an alternative reduced form approach that attempts to capture these missing effects by using empirical estimates of the effects of EU membership on trade and income implies that leaving the EU and joining EFTA would reduce UK income per capita by between 6.3% and 9.4%. We argue that falling FDI into the UK following Brexit (which is absent from the static model but implicitly captured by the dynamic model) explains some of the differences in the magnitude of the losses.

Our results show that the economic consequences of leaving the EU will depend upon the future of UK-EU trade relations. But in all our scenarios we find that lower trade due to reduced integration with EU countries is likely to cost the UK economy far more than is gained from lower contributions to the EU budget. Furthermore, these losses in welfare are shared relatively evenly across the income distribution. It is certainly not the case that the pain of Brexit will be born solely by the better off.

A contribution of the paper is to see how alternative methodologies and assumptions generate

different estimates of the costs and benefits of Brexit. We do not regard any single number as definitely "right" or "wrong". The exact magnitude of the effects will depend on the analyst's confidence in static trade theory based on structural work (where Brexit's harm is smaller in magnitude) compared to more empirically based reduced form work (where we uncover larger negative effects). What we have consistently found, however, is that UK citizens will pay an economic price for Brexit regardless of method or assumption. Moreover, these costs will be significantly higher in the case of a hard Brexit than a soft Brexit.

It may be that UK voters were aware of such costs and rationally chose to trade them off against the perceived non-economic benefits of Brexit (e.g. greater sovereignty and lower immigration). Survey evidence, however, suggests that most British voters did not believe that they would suffer any economic loss from Brexit [26]. Brexit has not yet happened. Our work suggests that when it does the average voter will suffer.

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[26] See, for example, $https://www.theguardian.com/politics/2016/jun/01/brexit-two-thirds-forsee-no-negative-impact-their-finances$

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Table 1: 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*	

Sources: 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 (4) and (7), 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 2: Sector and non-tariff barriers (NTB) used in the counterfactuals

Sector	(1) *NTB Cost EU+/USA (tariff equivalent)*	(2) *Reducible share of NTB*	(3) *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	56.8%	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	20.4%	0.54	–

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 US 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 US (optimistic scenario) or (ii) that after the exit the UK faces 3/4 of the reducible costs seen by the US (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 3: UK welfare change due to Brexit

Panel A: Optimistic Scenario	
Total Welfare Change	*-1.34%*
Income change per household	$-£893$
Panel B: Pessimistic Scenario	
Total Welfare Change	*-2.66%*
Income change per household	$-£1,773$

Notes: Counterfactuals changes in welfare, measured by consumption equivalent as specified by equation (5) with $\rho = 0.96$. 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 increase to 1/4th of the reducible barriers faced by US exporters to the EU (2.77% 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 (5.63% 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 1). Non-tariff barriers increase to 3/4th of the reducible barriers faced by US exporters to the EU (8.31% 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 (12.65% 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 4: Decomposition of the "Trade Effects" shown in Table 3

	Optimistic Scenario	Pessimistic Scenario
Rise in UK-EU Tariff		-0.13%
Rise in UK-EU NTB	-0.53%	-1.31%
No Future EU Integration	-0.90%	-1.61%

Notes: Decomposition of the "Trade Effects" shown in Table 3. Counterfactuals changes in welfare, measured by consumption equivalent as specified by equation (5) with $\rho = 0.96$. The numbers presented here do not sum up exactly to the ones observed in Table 3 because we are now performing three different counterfactual exercises (per scenario) instead of only one. EU is defined as EU 28 minus the UK and Croatia.
Column 2, row 1, shows an optimistic scenario where UK could negotiate a deal like Norway and tariffs remain zero. In column 2, row 2, non-tariff barriers increase to 1/4th of the reducible barriers faced by US exporters to the EU (2.77% increase). In column 2, row 3, 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 (5.63% lower in 10 years).
Column 3, row 1, shows a pessimistic scenario where the UK and EU impose MFN tariffs on each other (see Table 1). In column 3, row 2, non-tariff barriers increase to 3/4th of the reducible barriers faced by US exporters to the EU (8.31% increase). In column 3, row 3, the UK is excluded from further integration of EU where non-tariff barriers will fall 40% faster than in the rest of the world (12.65% lower in 10 years).

Table 5: Change in UK trade flows after Brexit

Scenario	Horizon	Total UK Export	Total UK Import	Export to EU	Import from EU
Optimistic Scenario	Short Run	-5%	-6%	-14%	-13%
	Long Run	-9%	-8%	-25%	-22%
Pessimistic Scenario	Short Run	-14%	-14%	-36%	-34%
	Long Run	-16%	-16%	-43%	-38%

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

Table 6: Impact of Brexit on living standards in different regions

	Optimistic		Pessimistic	
	Change in % Welfare	Change in GDP (£ bn)	Change in % Welfare	Change in GDP (£ bn)
UK	-1.34%	-25.0	-2.66%	-50.0
All EU countries except UK	-0.14%	-17.6	-0.35%	-34.0
Non-EU countries	0.01%	3.7	0.02%	7.4

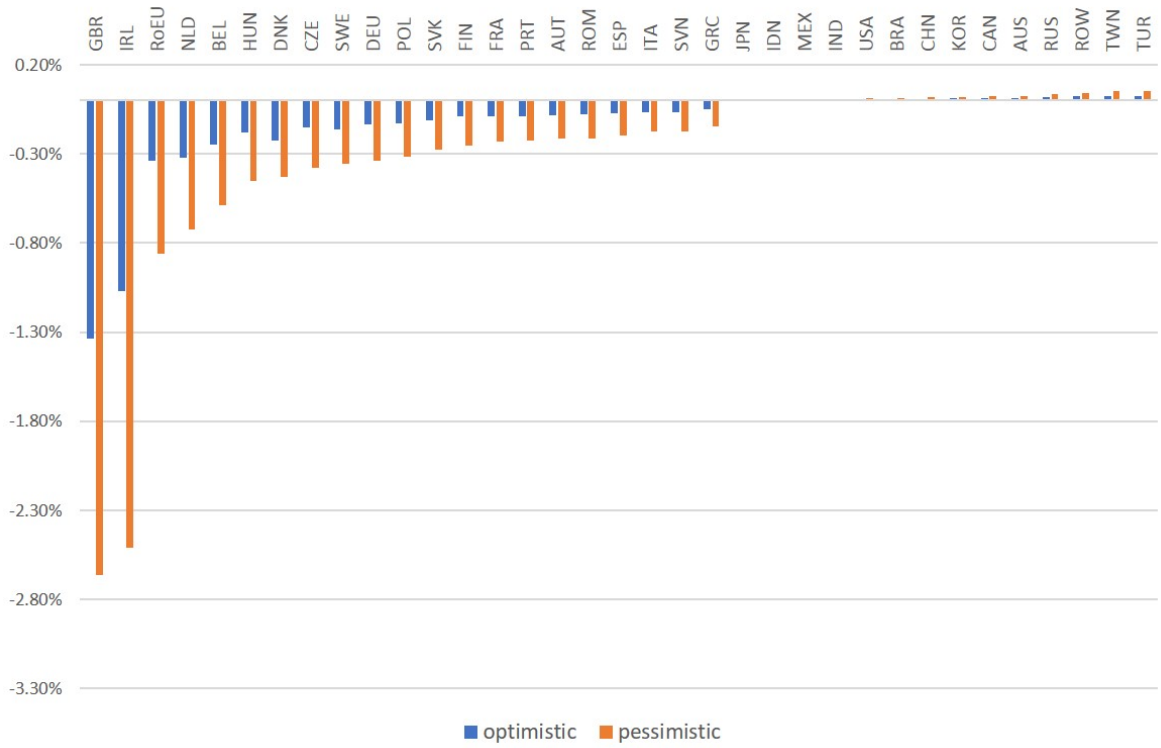
Notes: Same assumptions as in Pessimistic and Optimistic scenario in Table 3. The welfare loss of the EU countries except UK and non-EU countries are the weighted average of individual country's loss. The weight is given by GDP from IMF in £2014 https://www.imf.org/external/pubs/ft/weo/2014/02/weodata/index.aspx.

Table 7: Robustness on welfare change of UK due to Brexit

Panel A: Alternative scenarios		
Scenarios	A Swiss Alternative	Big Bang
Welfare Loss of UK	-1.44%	-3.84%
Panel B: Unilateral liberalisation of UK		
Scenarios	optimistic	pessimistic
Welfare Loss of UK	-1.05%	-2.34%
Panel C: UK welfare loss under different parameters		
Scenarios	optimistic	pessimistic
Discount factor: $\rho = 0.99$	-1.47%	-2.91%

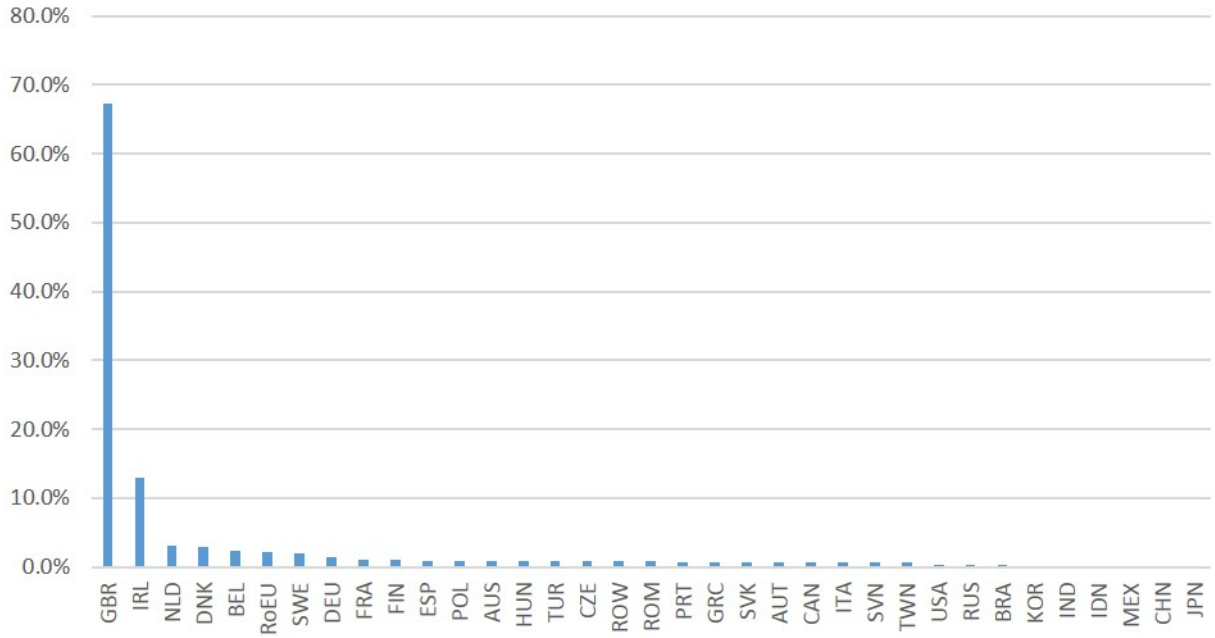
Notes: Panel A shows the results of the Swiss Alternative. Under such a scenario, the UK and EU still impose zero tariffs on goods flows. But unlike the optimistic scenario, the UK net fiscal contribution to EU would be lower but the non-tariff barriers would be higher for services. To be precise, we 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 to the full reducible barriers faced by US exporters to the EU (11.08%). Integration within the EU continue to be 40% faster than in the rest of world and 100% of the reducible price gaps could be reduced. Such integration happens right during the year of Brexit instead of taking 10 years. It leads to a reduction of non-tariff barriers among EU countries by 15.72%.
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 3. We first change the discount factor ρ from 0.96 to 0.99.

Figure 1: Welfare loss by country



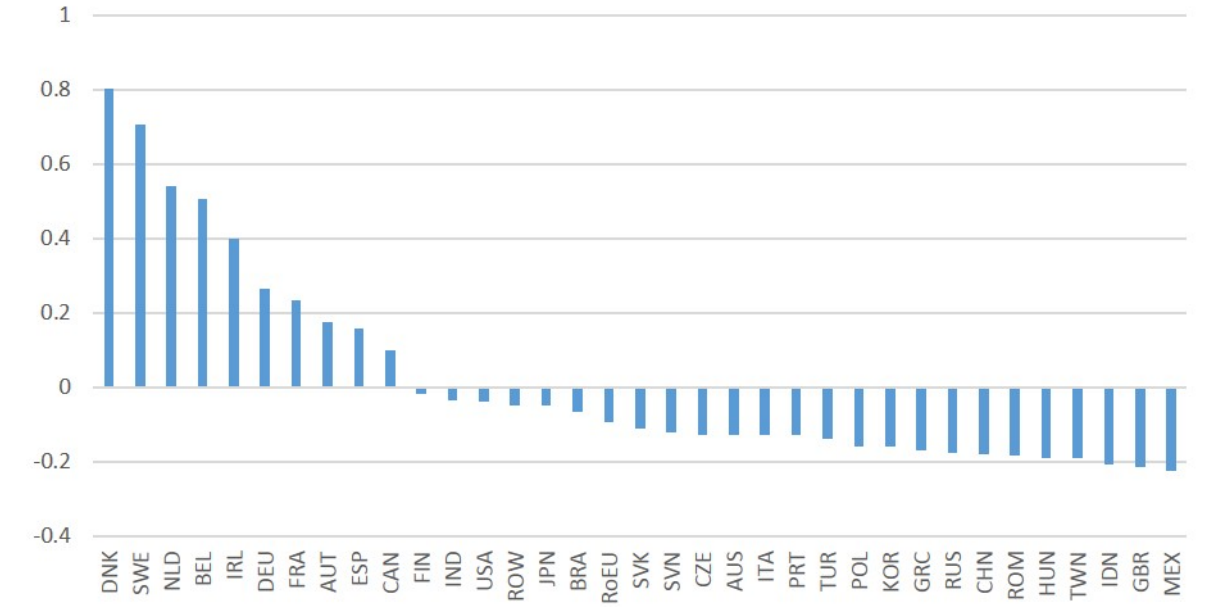
Notes: The figure plots the welfare loss by country for the optimistic and pessimistic scenario. Assumptions are the same as the notes to Table 3. We assume that the other EU countries have to fill the budget hole left by the UK proportionally to their GDP. This brings them a net fiscal loss of 0.015% in the optimistic case and 0.051% in the pessimistic case. The list of countries can be found in Table A.1.

Figure 2: Average Share (across sectors) of inputs sourced from the UK by country



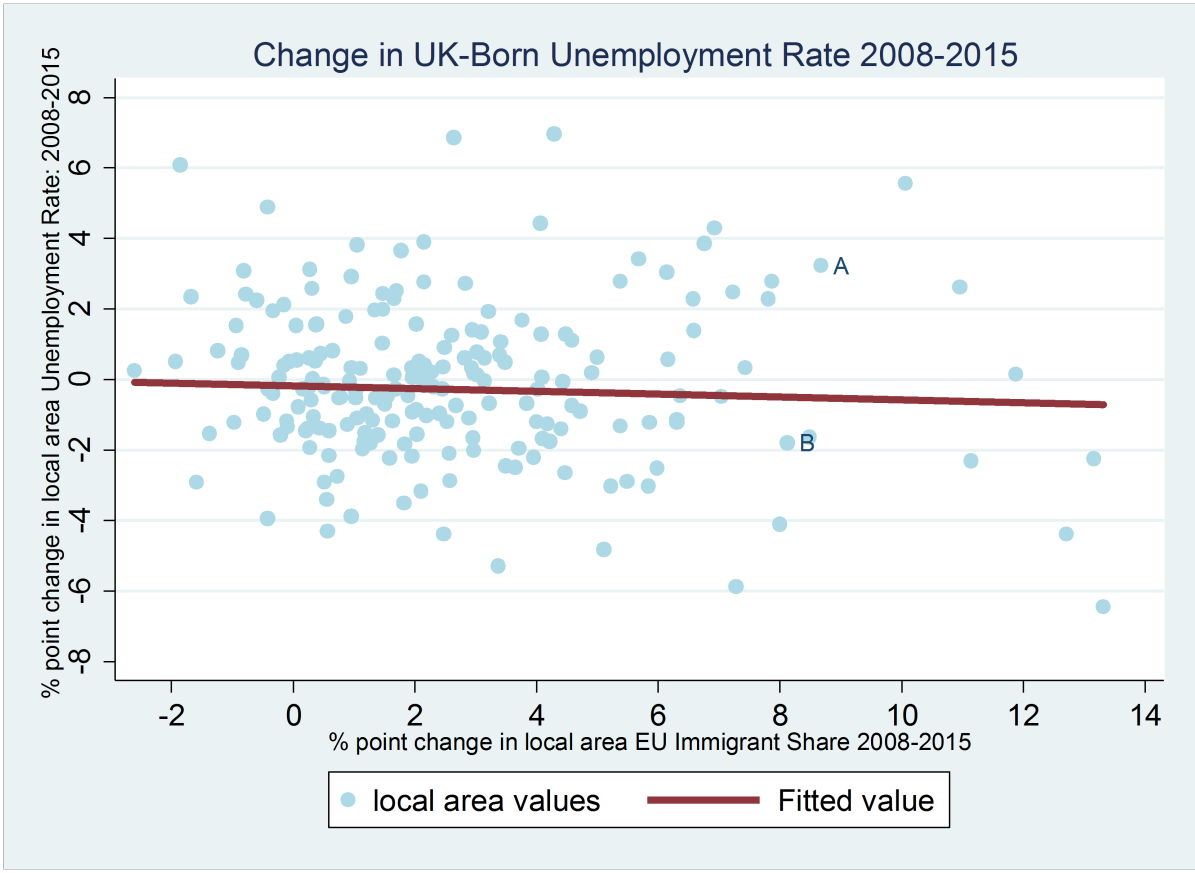
Notes: The figure plots the average share of UK intermediate inputs for each country across the 31 WIOD sectors in 2011.

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



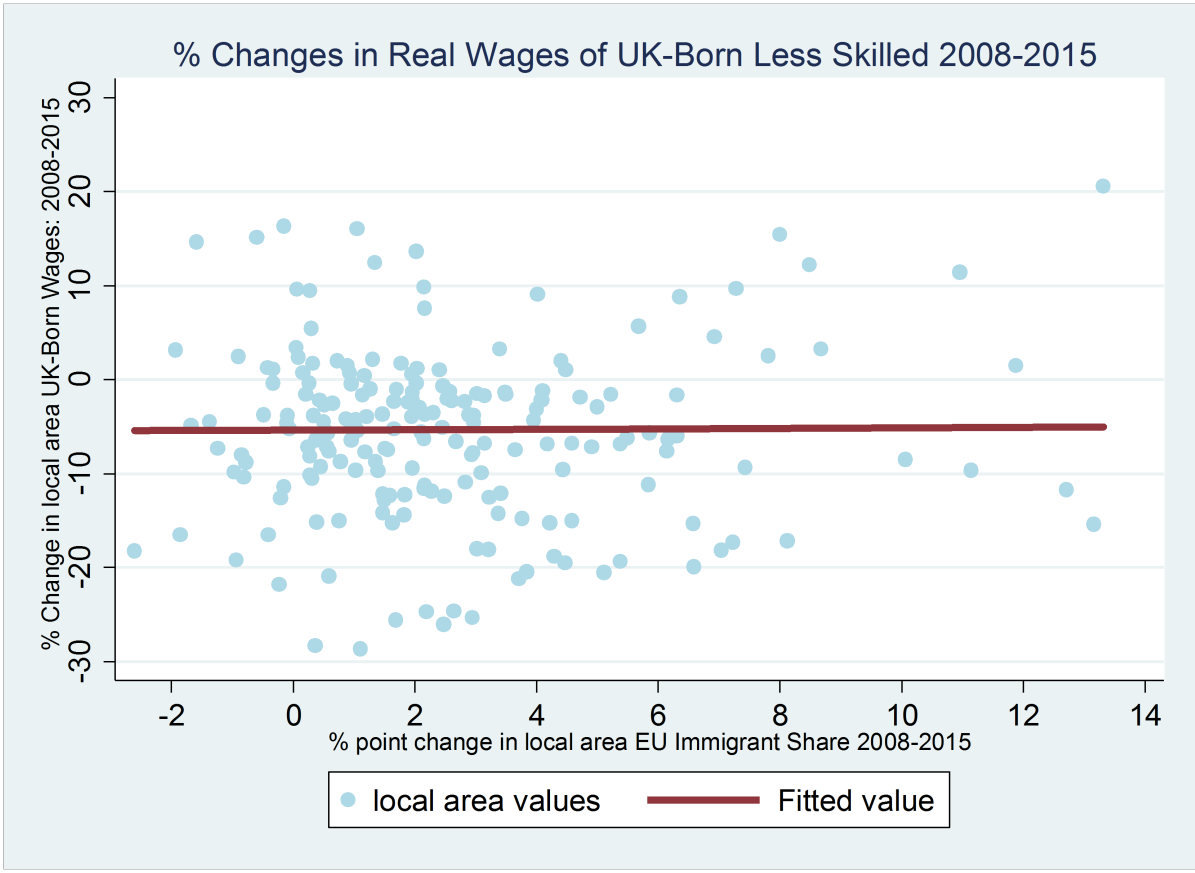
Notes: The figure plots the correlation between expenditure share on UK goods and the trade elasticity across 31 WIOD sectors for each country in 2011. Expenditure share is calculated using WIOD. Trade elasticity is presented in Table A.3.

Figure 4: Unemployment rates of UK-born and EU immigration



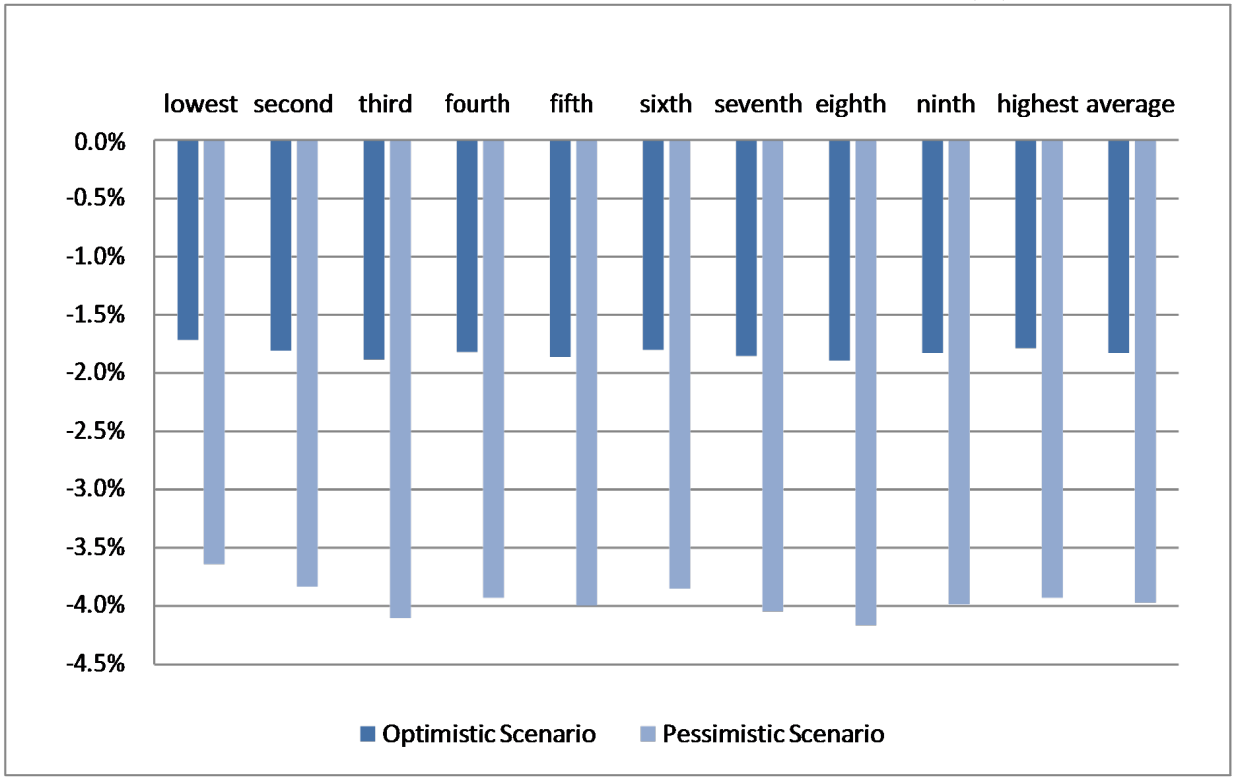
Source: Wadsworth, Dhingra, Ottaviano, and Van Reenen (2016), Labour Force Survey.
Notes: Each dot represents a UK local authority. The solid line is the predicted "best fit" from a regression of changes in unemployment on the change in share of EU immigrants in each UK local authority. These are weighted by the sample population in each area. Slope of this line is -0.04 with standard error of 0.05, statistically insignificantly different from zero.

Figure 5: Wage rates for less skilled UK-born and EU immigration



Source: Wadsworth, Dhingra, Ottaviano, and Van Reenen (2016), Labour Force Survey.
Notes: Each dot represents a UK local authority. The solid line is the predicted "best fit" from a regression of local authority percentage changes in the wages of the less skilled on the change in share of EU immigrants. These are weighted by the sample population in each area. Slope of this line is 0.02 with standard error of 0.21, statistically insignificantly different from zero. Less skilled is defined by those who left school at 16 or earlier.

Figure 6: Real income losses by household income decile (%)



Source: Breinlich, Dhingra, Sampson, and Van Reenen (2016), Labour Force Survey.
Notes: Predicted real income losses based on the present model, as calculated by Breinlich, Dhingra, Sampson, and Van Reenen (2016). See Table A2 in their paper in the Annex for the exact percentage changes for each income decile.

Appendix

A Tables

Table A.1: 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	
Luxembourg	LUX	
Malta	MLT	
Rest of World	ROW	ROW

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

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	2.47	1.89
Rubber and Plastics	5.25	5.28
Other Non-Metallic Mineral	4.80	3.49
Basic Metals and Fabricated Metal	1.47	1.00
Machinery, Nec	2.34	2.00
Electrical and Optical Equipment	1.83	1.70
Transport Equipment	5.55	6.26
Manufacturing, Nec; Recycling	1.44	1.76
Overall Weighted Average	2.94	2.86

Source: UN Comtrade comtrade.un.org/ and WTO http://tariffdata.wto.org/.
Note: Tariff used in the case of UK unilaterally liberalisation. 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: Trade elasticity per sector

WIOD 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 Rodríguez-Clare, 2014). The trade elasticities for the tradable sectors are estimated by Caliendo and Parro (2015). For the service sector, we follow (Costinot and Rodríguez-Clare, 2014) to set them as 5.

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 trade cost is given by:

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

For example, the reduction in the reducible trade costs is $\Delta\tau_{10}^R = \tau_0^R - \tau_0^{R(1-d)^{10}}$ in year 10. Finally, the shock to the total trade cost is $\widehat{\tau}_t = \frac{\tau_t}{\tau} = \frac{\tau+\Delta\tau_t^R}{\tau}$.

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), Méjean and Schwellnus (2009) point out that 55% of the trade cost is reducible, 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.

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