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TRADE LIBERALIZATION WITH HETEROGENEOUS WORKERS: A STRUCTURAL APPROACH

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Abstract

We build a multi-sector general equilibrium model of trade and production with heterogeneous workers. The model features intersectoral linkages on the demand side, via consumption substitution links, and intersectoral linkages on the supply side, via the use of intermediates. Importantly, we also allow for three different types of workers, based on education, who can be affected differentially by trade. Thus, the model can be used to study the implications of trade liberalization for both across- and within-country income inequality. To demonstrate the usefulness and effectiveness of our methods, we employ a data set of 45 countries and 22 sectors in 2010 to simulate the effects of the hypothetical formation of a regional trade agreement (RTA) between the United Stated and Great Britain.

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1 Introduction and Motivation

Globalization has brought many benefits, but it has not benefited everyone. Some workers do not feel enriched by globalization. Instead, they feel hurt by the intensive integration and trade liberalization efforts that took place in the past quarter century. These workers have become a significant political force. "Some 58% of people in professional and higher management jobs [in Great Britain] wanted to remain [in the European Union] compared with only 27% of people in unskilled jobs. Not surprisingly, high-status individuals with marketable skills favour UK membership of the EU, whereas people who lack these skills and are vulnerable in the labour market are opposed." (*Independent*, UK, June 26, 2016).

At the same time, stimulated by the elegant and intuitive theories of Eaton and Kortum (2002) and Anderson and van Wincoop (2003) and by the remarkable empirical success of the structural gravity model, the academic field of international trade witnessed the rise of a new generation of computable general equilibrium (CGE) trade models with solid theoretical foundations and and tight connection to the data, cf. Costinot and Rodríguez-Clare (2014).[1]

We augment a structural gravity model with worker heterogeneity, which allows us to link trade and labor market outcomes and quantify the impact of trade liberalization (or, alternatively a move toward autarky) simultaneously on across- and within-country income inequality. Our tractable general equilibrium trade framework incorporates multiple countries, multiple industries, inter-industry linkages on the supply and on the demand side, and, most importantly, different types of labor.

Our model complements and extends a series of recent sectoral gravity models (e.g. Egger, Larch and Staub, 2012; Costinot, Donaldson and Komunjer, 2012; Shikher, 2011; Larch and Wanner, 2014; Caliendo and Parro, 2015; Anderson and Yotov, 2016). While

[1] Some examples include Anderson and Yotov (2010*a*), Egger et al. (2011), Egger and Larch (2011), Ossa (2011), Fieler (2011), Shikher (2011), Costinot, Donaldson and Komunjer (2012), Eaton, Kortum and Sotelo (2013), Arkolakis et al. (2013), Behrens et al. (2014), Allen, Arkolakis and Takahashi (2014), Felbermayr et al. (2015), Heid (2015), Caliendo and Parro (2015), Caliendo, Dvorkin and Parro (2015), Heid and Larch (2016), Anderson, Larch and Yotov (2015*b*), and Eaton et al. (2016). Anderson (2011), Head and Mayer (2014), Costinot and Rodríguez-Clare (2014), and Larch and Yotov (2016) offer reviews of this literature and its development over time.

intermediates still play a key role both in our theory and in the empirical analysis, the main difference between our framework and this previous literature is that our model also includes heterogeneous types of labor.

The links between trade and labor market outcomes have been previously studied using a variety of methodologies and data from past trade liberalization episodes. For example, Haskel and Slaughter (2003) find that in 1970s and 1980s cuts in tariffs and transportation costs in the United States mostly occurred in the low skill intensive industries. However, they find that falling tariffs and transport costs did not result in significant rise in inequality. Autor, Dorn and Hanson (2013) find that increased Chinese imports had negative effects on local labor markets in the United States. Caliendo, Dvorkin and Parro (2015) study the effects of increased Chinese imports on US labor markets at the state level using a dynamic labor search model.

McLaren and Hakobyan (2016) use US Census data to estimate effects of NAFTA on US wages disaggregated by industry, location, and also education. They find that wages of blue-collar workers in some industries and localities were significantly negatively affected. Caliendo and Parro (2015) use a computable model to show that NAFTA resulted in an overall increase in US real wages. Lee (2017) extends the Eaton-Kortum model to include worker heterogeneity, which allows her to study the link between trade and inequality. Haskel et al. (2012) provide a review of the literature on the effects of globalization on US wages.

In comparison to some of these papers, we contribute by using a structural approach. In comparison to the newer papers that also use a structural approach, e.g. Caliendo, Dvorkin and Parro (2015), we introduce heterogeneous workers.[2] In comparison to Lee (2017), our model is easier to solve quantitatively and can provide a much more detailed industry breakdown and analysis.[3] We also account for differences in education quality

[2]There is also a literature that studies transitional dynamics and costs of adjustment to new trade policy. These short-term effects are not part of our model. Instead, we focus on medium- and long-term effects of trade on labor markets.

[3]The computational complexity arises from several layers of productivity heterogeneity that exist in her model.

across countries.

Our model generates clear predictions about two channels though which trade liberalization may affect the demand for each type of labor in each country and in each sector. The first channel is via the outward multilateral resistance index of Anderson and van Wincoop (2003), which measures the incidence of trade costs on the producers in each sector and in each country. The relationship is inverse. Intuitively, a higher multilateral resistance for the producers in a given sector translates into lower factory gate prices, which, in turn, lead to lower demand for all factors of production, including each type of labor in this industry. Importantly, since the outward multilateral resistance is a general equilibrium index, the demand for labor of each type can be affected by changes in trade costs in any country in the world. Finally, we note that the impact of trade liberalization via this channel will be stronger when the share of this labor's type is in production is larger.

The second channel through which trade liberalization affects labor market outcomes is via the inward multilateral resistance, which measures the incidence of trade costs on the consumers (of both final and intermediate goods) in each country. Once again, the relationship is inverse. The intuition behind this result is that the inward multilateral resistance appears in the theoretical demand equations for each type of labor as the price of intermediate goods. Thus, when intermediates become more expensive consumers will substitute away from them and in favor of other production factors including labor of each type. Importantly, the impact of trade liberalization via this channel captures several general equilibrium relationships both at the country and at the sectoral level. At the extreme, this channel implies that a change in trade costs in any sector and in any country may affect the demand for a specific type of labor in any other sector and other country in the world. The strength of such impact will depend on how strong are the input-output links in the world trade and production system as well as on the share of the labor's type in production.

In order to demonstrate the effectiveness of our theory and to show how the model can be used in trade policy analysis, we quantify the impact of a hypothetical regional trade agreement between the US and Great Britain with a novel dataset that covers 22 sectors and 45 countries in 2010 and includes data on international trade flows, production, three types of labor, and wages, all at the sectoral level. The three types of labor are distinguished by education: primary, secondary, and tertiary. We assemble a unique collection of data regarding the use of these three types of labor in various industries and countries, and their wages. Differential use of the three types of labor across industries combine with different costs of these types of labor in various countries to create a Heckscher-Ohlin motive for trade.

We use an empirical gravity model to construct trade costs. This enables us to confirm that gravity works well at the sectoral level. Then, we combine our trade cost estimates with actual data and values for the other structural parameters, which we construct directly from the data, calibrate from the structural model, or simply borrow from the literature.

Our model generates the effects of a new US-UK RTA on macroeconomic, industry-specific, and labor market variables. Importantly, it generates separate effects on the three types of labor distinguished by education. For brevity and for expositional simplicity, we focus on two sets of results, which are obtained from a version of our model that allows for reallocation of labor of each type. The first set of estimates includes a series of cross-section indexes at the country level that are obtained as aggregates across all sectors for each country in our sample. Overall, the results are intuitive and with reasonable magnitudes. We find that Great Britain gains the most in terms of total exports (an increase of about 12 percent), in terms of lower prices (a fall of 0.7 percent), and in terms of real GDP (an increase of 3.6 percent). The United States gains too, but the gains are much smaller. Specifically, our estimates suggest that US total exports will increase by about 3 percent, consumer prices will fall by 0.12 percent, and real GDP will increase by about 1 percent. Country size is a natural explanation for the differential effects of the bilateral agreement on the two economies.

An UK-US RTA will also affect all other countries in the world. Our estimates reveal that the effects on outside countries will be relatively small. However, we do find these effects vary intuitively with larger losses for countries that are more closely related (economically and geographically) to the two liberalizing nations. Thus, for example, the largest negative impact of -0.42 percent is for the real GDP of the Dominican Republic, followed by Ireland and Mexico. The average real GDP change across all outside countries is -0.11 percent. Based on these results, we conclude that the US-UK RTA may have significant implications for the member countries, however, the implications for income-inequality in the rest of the world will be quite small.

The second set of estimates that we obtain and discuss in the main text are the GE effects of the UK-US RTA on individual sectors and labor types in the United States. Our results reveal significant variation in the effects of the agreement on sectoral US exports. Specifically, we find that the sectors that will gain the most include Manufacture of wood, Manufacture of machinery and equipment, and Manufacture of radio, television and communication equipment and apparatus. The smallest increase will be observed in Manufacture of tobacco products and Manufacture of wearing apparel; dressing and dyeing of fur. Interestingly, despite an initial positive impact of the UK-US RTA, we also document a decrease in US exports in Other Manufacturing. The explanation for this result is a combination of strong GE forces and a very strong positive impact for UK exports in this industry.

We also take advantage of the ability of our model to capture the effects of trade liberalization on heterogeneous labor. Two main findings stand out from the sectoral estimates for the United States. First, we find that the number of workers employed in some sectors will increase, while the number of workers employed in other sectors will fall. The sectors that will accept the largest number of new workers are Manufacture of radio, television and communication equipment and apparatus, Manufacture of textiles, Manufacture of wood and of products of wood and cork, except furniture, and Manufacture of paper and paper products. This is expected since these are exactly the sectors for which our model predicts that producer prices and production will increase the most. Our estimates suggest that the number of workers will actually decrease in more than half of the US sectors. The biggest negative impact on labor will be felt in the sectors where exports decrease (or increase the least). These sectors include Tanning and dressing of leather; manufacture of luggage, footwear, etc., Manufacture of furniture; manufacturing n.e.c., Manufacture of office, accounting and computing machinery, and Manufacture of wearing apparel; dressing and dyeing of fur.

Second, despite the fact that we are considering a hypothetical trade liberalization scenario between two very similar economies, we do obtain differential effects on labor across the different types of workers in each country. Specifically, a comparison between the effects on labor with primary and with higher education reveals that the number of workers with the highest level of education in US will increase more in the industries that hire more workers and will decrease less in the industries that let workers go. All else equal, this points to potential increase in income inequality in the US even from trade liberalization within a very similar developed partner such as the UK.

The corresponding estimates for the United Kingdom reveal that the impact on labor in the UK will be stronger and that the differential impact of the UK-US agreement on the different types of workers is more pronounced in the UK. Relative size between the liberalizing partners is a natural explanation for this result. In addition, we find that the UK-US RTA will lead to a stronger negative impact and to a weaker positive effect on the workers with the highest education as compared to the less educated workers, thus pointing to a potential decrease in income inequality in the UK.

The remainder of the paper is organized as follows. Section 2 develops our theoretical model. Section 3 discusses our simulation approach. Section 4 describes the data and the data sources. Section 5 presents and discusses sectoral gravity estimates. Section 6 describes the analysis of the general equilibrium impact of a hypothetical RTA between the United States and Great Britain. Section 7 concludes and discusses possible extensions. Finally, the Appendix offers some additional empirical results and robustness analysis.

2 Sectoral Gravity with Skills and Intermediates

This section develops a sectoral general equilibrium trade model with intermediate inputs and three types of labor and discusses our contributions in light of the previous literature.

Consumption. On the demand side, we employ a two-tier utility specification, which has become standard in the trade literature. At the upper level, consumers choose across goods from different industries k subject to Cobb-Douglas (CD) preferences, which translate into constant expenditure shares such that total expenditures on goods from industry k in country j are:

$$\left(E_j^k\right)^c = \psi^k I_j, \tag{1}$$

where, superscript c is used to denote consumption of final goods,[4] $\psi^k \geq 0$, $\sum_k \psi^k = 1$, is a globally common CD share parameter, and $I_j = \sum_k I_j^k$ is the total income of consumers in country j. The Cobb-Douglas preferences across goods nest Constant Elasticity of Substitution (CES) preferences across varieties i within each industry:

$$\left(\sum_i \beta_i^{k\frac{1-\sigma^k}{\sigma^k}} c_{ij}^{k\frac{\sigma^k-1}{\sigma^k}}\right)^{\frac{\sigma^k}{\sigma^k-1}}. \tag{2}$$

Here, c_{ij} is consumption in destination j of goods in industry k imported from origin i; σ_k is the elasticity of substitution for goods in industry k; and β_i^k is a CES share parameter. Given the level of total expenditure in each industry, $\left(E_j^k\right)^c$, consumers maximize (2) subject to a series of standard budget constraints:

$$\sum_i p_{ij}^k c_{ij}^k = \left(E_j^k\right)^c, \qquad \forall k, j. \tag{3}$$

Equation (3) simply states that expenditure on consumption for each type of good k in each country j is the sum of bilateral expenditures from all possible partners including country j

[4]Below, we will introduce expenditure on intermediates, $\left(E_j^k\right)^m$, where the superscript m will be used to denote intermediates.

itself, at delivered prices p_{ij}^k. Here, $p_{ij}^k = p_i^k t_{ij}^k$ is the price of origin i goods in industry k for region j and $t_{ij}^k \geq 1$ denotes the standard iceberg variable trade cost factor on shipment of goods in industry k from i to j.

Solving the consumer's problem obtains the demand for consumption goods c of industry k shipped from origin i to destination j as:

$$(x_{ij}^k)^c = (\beta_i^k p_i^k t_{ij}^k / P_j^k)^{(1-\sigma^k)} \left(E_j^k\right)^c, \quad (4)$$

where, for now, $P_j^k = [\sum_i (\beta_i^k p_i^k t_{ij}^k)^{1-\sigma^k}]^{1/(1-\sigma^k)}$ is the standard CES price aggregator. Following Anderson and van Wincoop (2003), below P_j^k will be redefined as 'inward multilateral resistance'. However, retaining the meaning of P_j^k in their role as CES aggregators, the inward multilateral resistances may, in principle, be interpreted as *ideal price indexes*, and their variation across countries might be expected to reflect variation in consumer price indexes (CPIs).[5]

Production. Production in each sector $k' \in K$ in country j uses domestic factors of production including sector-specific domestic technology $A_j^{k'}$;[6] and sector-specific domestic labor, $L_j^{k',s}$, with different skills $s \in S$. In addition, production in each sector also employs intermediates $M_j^{k,k'}$ from every other sector k, including own intermediates.[7] Thus, the output in a given sector is split between two uses: final consumption and intermediate use for production, which both are internationally traded. All factors of production in sector k'

[5]The IMRs may have more variation than the corresponding CPIs and the former may only loosely track variations in consumer price indexes. See Anderson and Yotov (2010*a*) for a discussion on the differences between the IMRs and the CPIs.

[6]Since capital is not explicitly introduced in our analysis, $A_j^{k'}$ should be thought of as capital-augmented technology.

[7]To model intermediates we essentially follow Eaton and Kortum (2002). The original Eaton-Kortum model was recently extended to accommodate intermediates at the sectoral level by Shikher (2012) and Caliendo and Parro (2015). On that front, our analysis is parallel to those of Caliendo and Parro (2015). The expositional difference is that we are building a sectoral model with intermediates on the basis on the demand-side gravity models of Anderson (1979) and Anderson and van Wincoop (2003), while Caliendo and Parro (2015) depart from the supply-side gravity foundation of Eaton and Kortum (2002). Larch and Yotov (2016) use the demand-side notation to re-derive various versions of the Eaton and Kortum (2002) model to demonstrate that the basic aggregate and sectoral supply-side and demand-side gravity models are indeed identical subject to parameter interpretation.

in country j are combined subject to a Cobb-Douglas production function, which results in the following specification for the value of production:

$$Y_j^{k'} = p_j^{k'} A_j^{k'} \prod_{s=1}^{S} \left(L_j^{k',s}\right)^{\alpha_j^{k',s}} \prod_{k=1}^{K} \left(M_j^{k,k'}\right)^{\alpha_j^{k,k'}} . \tag{5}$$

Here, $Y_j^{k'}$ is sectoral income/value of production in country j. $p_j^{k'}$ is the corresponding factory-gate price. $L_j^{k',s}$ is the number of workers of skill type s who are employed in sector k' in country j, and $\alpha_j^{k',s}$ is the corresponding labor share in production, $\sum_s \alpha_j^{k',s} + \sum_k \alpha_j^{k,k'} = 1$. Finally, the amount of intermediates from sector k used in sector k' in country j is defined as a CES composite of domestic components, $m_{jj}^{k,k'}$, and imported components,, $m_{ij}^{k,k'}$, from all other countries $i \neq j$:

$$M_j^{k,k'} = \left(\sum_i \beta_i^{k\,\frac{1-\sigma^k}{\sigma^k}} m_{ij}^{k,k'\,\frac{\sigma^k-1}{\sigma^k}} \right)^{\frac{\sigma^k}{\sigma^k-1}} . \tag{6}$$

As is standard in most models with intermediates, we assume that the elasticity of substitution within industry k is the for the consumption and intermediate inputs.

With perfectly competitive markets, factors are paid the values of their marginal products. This enables us to express the the wages for the different labor types as:[8]

$$w_j^{k',s} = \alpha_j^{k',s} Y_j^{k'} / L_j^{k',s}. \tag{7}$$

(7) implies that the income of workers of type s in industry k' in country j is a constant share of $Y_j^{k'}$ or:

$$w_j^{k',s} L_j^{k',s} = \alpha_j^{k',s} Y_j^{k'}. \tag{8}$$

Thus, the total income of all workers in industry k' in country j can be obtained after

[8] Alternatively, the demand equation (7) can be used to solve for the amount of labor $L_j^{k',s}$.

summing across all types of labor:

$$\sum_s w_j^{k',s} L_j^{k',s} = \sum_s \alpha_j^{k',s} Y_j^{k'}. \tag{9}$$

Finally, the total income of all workers in country j is obtained after summing labor income across all sectors k':

$$I_j = \sum_{k'} \sum_s w_j^{k',s} L_j^{k',s} = \sum_{k'} \sum_s \alpha_j^{k',s} Y_j^{k'}. \tag{10}$$

In combination with equation (1), equation (10) implies that the total expenditure (E) on consumption goods (c) from industry k in country j can be expressed as:

$$\left(E_j^k\right)^c = \psi^k I_j = \psi^k \sum_{k'} \sum_s \alpha_j^{k',s} Y_j^{k'}. \tag{11}$$

Turning to the demand for intermediates, we can solve for the demand for composite intermediates k used in sector k' as:

$$M_j^{k,k'} = \alpha_j^{k,k'} Y_j^{k'} / P_j^k. \tag{12}$$

Equation (12) implies that total expenditure (E) on intermediates (m) from industry k in country j can be expressed as the sum of the expenditure on those intermediates in each sector k':

$$\left(E_j^k\right)^m = \sum_{k'} P_j^k M_j^{k,k'} = \sum_{k'} \alpha_j^{k,k'} Y_j^{k'}. \tag{13}$$

Note also that we can express the total expenditure on intermediates that are used for production in sector k' as the sum across the expenditure on intermediates across all sectors k:

$$\sum_k P_j^k M_j^{k,k'} = \sum_k \alpha_j^{k,k'} Y_j^{k'}. \tag{14}$$

This will enable us to obtain an alternative expression for the total income of labor in sector k' as the difference between the total value generated in this sector, $Y_j^{k'}$, less the payments for all the intermediates that are used for production in k':

$$I_j^{k'} = Y_j^{k'} - \sum_k \alpha_j^{k,k'} Y_j^{k'} \tag{15}$$

Finally, combining equation (12) with the definition of intermediates as CES composites of domestic and foreign varieties (6), we can also solve for the nominal demand of intermediate varieties m in sector k that are exported from source i for production in sector k' at destination j as:

$$\left(x_{ij}^{k,k'}\right)^m = (\beta_i^k p_i^k t_{ij}^k / P_j^k)^{(1-\sigma^k)} \alpha_j^{k,k'} Y_j^{k'}, \tag{16}$$

where, $p_{ij}^k = p_i^k t_{ij}^k$ is the price of origin i goods in industry k for region j and $t_{ij}^k \geq 1$ denotes the standard iceberg variable trade cost factor on shipment of goods in industry k from i to j. $P_j^k = [\sum_i (\beta_i^k p_i^k t_{ij}^k)^{1-\sigma^k}]^{1/(1-\sigma^k)}$ is the standard CES price aggregator. Thus, we can express the total demand in country j for intermediates in sector k from country i as the sum of the bilateral demands across all sectors $k' \in K$:

$$\left(x_{ij}^k\right)^m = \sum_{k'} (\beta_i^k p_i^k t_{ij}^k / P_j^k)^{(1-\sigma^k)} \alpha_j^{k,k'} Y_j^{k'} = (\beta_i^k p_i^k t_{ij}^k / P_j^k)^{(1-\sigma^k)} \left(E_j^k\right)^m, \tag{17}$$

where, to obtain the rightmost equation, we have employed the definition of the expenditure on intermediates from equation (13). In addition to the standard relationships between the demand for intermediate goods and their prices, equation (17) captures the intuitive link that more intermediates will be demanded, the larger their share in production in each sector, $\alpha_j^{k,k'}$, and the larger the size of the sectors that they are used in, $Y_j^{k'}$.

Closing the Model. The total bilateral demand for goods in industry k from country i in country j is equal to the sum of the bilateral demand for consumption goods $(x_{ij}^k)^c$, and the bilateral demand for the goods in industry k as intermediates $(x_{ij}^k)^m$:

$$X_{ij}^k = (x_{ij}^k)^c + (x_{ij}^k)^m. \tag{18}$$

Substitute in (18) the demand expressions for final consumption and for the intermediate use from equations (4) and (17), respectively, and simplify to obtain:

$$X_{ij}^k = (\beta_i^k p_i^k t_{ij}^k / P_j^k)^{(1-\sigma^k)} \left(\left(E_j^k\right)^c + \left(E_j^k\right)^m \right). \tag{19}$$

Use the solution for expenditure on consumption goods in industry k, $\left(E_j^k\right)^c$, from equation (11), and the solution for expenditure on intermediate goods in industry k, $\left(E_j^k\right)^m$, from equation (13), and define:

$$E_j^k \equiv \left(E_j^k\right)^c + \left(E_j^k\right)^m = \psi^k \sum_{k'} \sum_s \alpha_j^{k',s} Y_j^{k'} + \sum_{k'} \alpha_j^{k,k'} Y_j^{k'}. \tag{20}$$

Impose market clearance for goods in each industry from each origin, so that (at delivered prices) the total value of production of goods k in country i, Y_i^k, is equal to the sum of total final consumption of these goods across all countries, $\sum_j (x_{ij}^k)^c$, and the total consumption of these goods as intermediates in production across all sectors and all countries, $\sum_j (x_{ij}^k)^m$:

$$Y_i^k = \sum_j X_{ij}^k = \sum_j (\beta_i^k p_i^k t_{ij}^k / P_j^k)^{(1-\sigma^k)} E_j^k. \tag{21}$$

Define $Y^k \equiv \sum_i Y_i^k$ and divide the preceding equation by Y^k to obtain:

$$Y_i^k / Y^k = (\beta_i^k p_i^k \Pi_i^k)^{1-\sigma^k}, \tag{22}$$

where $\Pi_i^k \equiv \sum_j (t_{ij}^k / P_j^k)^{1-\sigma^k} \frac{E_j^k}{Y^k}$. Finally, use (22) to substitute for $\beta_i^k p_i^k$ in the CES price index P_j^k:

$$(P_j^k)^{1-\sigma^k} = \sum_i \left(\frac{t_{ij}^k}{\Pi_i^k} \right)^{1-\sigma^k} \frac{Y_i^k}{Y^k}, \tag{23}$$

and use the solution for $\beta_i^k p_i^k$ from (22) and the definition of E_j^k to substitute in the demand equation (19):

$$X_{ij}^k = \frac{Y_i^k E_j^k}{Y^k}\left(\frac{t_{ij}^k}{\Pi_i^k P_j^k}\right)^{1-\sigma^k}, \tag{24}$$

Then, collect equations to obtain a familiar system:

$$X_{ij}^k = \frac{Y_i^k E_j^k}{Y^k}\left(\frac{t_{ij}^k}{\Pi_i^k P_j^k}\right)^{1-\sigma^k}, \tag{25}$$

$$(\Pi_i^k)^{1-\sigma^k} = \sum_j \left(\frac{t_{ij}^k}{P_j^k}\right)^{1-\sigma^k} \frac{E_j^k}{Y^k}, \tag{26}$$

$$(P_j^k)^{1-\sigma^k} = \sum_i \left(\frac{t_{ij}^k}{\Pi_i^k}\right)^{1-\sigma^k} \frac{Y_i^k}{Y^k}, \tag{27}$$

$$p_i^k = \left(\frac{Y_i^k}{Y^k}\right)^{\frac{1}{1-\sigma^k}} \frac{1}{\beta_i^k \Pi_i^k}, \tag{28}$$

$$Y^k = \sum_i Y_i^k = \sum_i p_j^k A_j^k \prod_{s=1}^{S}\left(L_j^{k,s}\right)^{\alpha_j^{k,s}} \prod_{k'=1}^{K}\left(M_j^{k',k}\right)^{\alpha_j^{k',k}}, \tag{29}$$

$$E_j^k = \psi^k \sum_{k'}\sum_s \alpha_j^{k',s} Y_j^{k'} + \sum_{k'} \alpha_j^{k,k'} Y_j^{k'}, \tag{30}$$

$$M_j^{k,k'} = \alpha_j^{k,k'} Y_j^{k'} / P_j^k, \tag{31}$$

$$L_j^{k',s} = \left[\frac{\alpha_j^{k',s}}{w_j^{k',s}}\left(\frac{Y_j^{k'}}{Y^{k'}}\right)^{\frac{1}{1-\sigma^{k'}}} \frac{A_j^{k'}}{\beta_j^{k'}\Pi_j^{k'}} \prod_{s'\neq s}\left(L_j^{k',s'}\right)^{\alpha_j^{k',s'}} \prod_{k=1}^{K}\left(\frac{\alpha_j^{k,k'} Y_j^{k'}}{P_j^k}\right)^{\alpha_j^{k,k'}}\right]^{\frac{1}{1-\alpha_j^{k',s}}}, \tag{32}$$

$$L_j^s = \sum_k L_j^{k,s}. \tag{33}$$

The equations in system (25)-(33) are intuitive and most of them are familiar since, as we demonstrate next, the system nests a series of influential theoretical models from the structural gravity literature. Equation (25) is the traditional structural gravity equation, which has served as a theoretical foundation to hundreds of empirical papers that study the determinants of bilateral trade flows. Intuitively, equation (25) captures the fact that trade between two countries is proportional to their sizes and inversely proportional to the trade frictions between them.

In combination, equations (26)-(27) are the equations for the multilateral resistances of Anderson and van Wincoop (2003). The multilateral resistances are general equilibrium indexes that consistently aggregate all possible bilateral trade cost links t_{ij} to the country level, and decompose the incidence of trade costs on the consumers (*Inward Multilateral Resistance, IMR*) and the producers (*Outward Multilateral Resistance, OMR*) in each country and sector, as is they ship to a unified world market. Larch and Yotov (2016) offer a detailed description of the main properties and importance of the MR terms.

Equation (28) is a version of the goods market-clearing condition, which states that, at delivered prices, the value of production in each sector should be equal to the total expenditure on the goods from this sector in the world, including domestic sales. Restated in the form of (28), the market-clearing condition clearly demonstrates the inverse relationship between the outward multilateral resistance and factory-gate prices. Combining the market-clearing conditions (28) with equations (25)-(27) corresponds directly to the sectoral gravity system of Anderson and Yotov (2016), which demonstrates the sectoral separability of the structural gravity model and allows for inter-sectoral linkages that arise on the demand side, i.e. due to the substitutability of goods across goods industries. The sectoral gravity system (25)-(28) nests the original aggregate systems of Anderson (1979) and Anderson and van Wincoop (2003), on the demand side, and Eaton and Kortum (2002), on the supply side.[9]

As defined earlier, equation (29) is the production value function and equation (30) is the expenditure in sector k, which is a combination of expenditure on final goods and expenditure

[9] As demonstrated by Arkolakis, Costinot and Rodriguez-Clare (2012), the structural gravity systems of Anderson (1979), Anderson and van Wincoop (2003), and Eaton and Kortum (2002) can be obtained from a wide range of theoretical micro foundations. SeeHead and Mayer (2014), Costinot and Rodríguez-Clare (2014), and Larch and Yotov (2016) for informative surveys of the literature.

on intermediates. The demand for intermediates is captured by Equation (31). Intuitively, the demand for intermediates is proportional to a sector's size and inversely proportional to the price of intermediates. In combination, equations (25)-(31) correspond directly to the sectoral gravity system with intermediates from the influential paper by Caliendo and Parro (2015). The role of intermediates can clearly be seen from equations (29) and (30). Equation (29) accounts for the use of intermediates in production, while equation (30) captures the fact that the expenditure on goods from industry k in each country is split between expenditure on final goods and on intermediate goods from this industry. The structural links with intermediates on the production side imply that changes in trade policy between any pair of countries and each sector in the world will have ripple effects through all other sectors and countries.

Finally, and most important for the current purposes, the last two equations from system (25)-(33) are the labor market equations in our model. Equations (32) and (33) reflect the introduction of a labor market with different types of workers, which is our main contribution relative to existing literature. Equation (33) is the market-clearing equation for labor of each type s. Equation (45) is the equation for labor demand by sector and by type of skill, which is central for our analysis. Equation (45) captures several well-established and intuitive relationships as well as the novel links through which trade affects the sectoral demand for labor of each type. Specifically, for each type of labor in each sector, equation (45) captures the inverse (and standrad) relationship between the quantity of labor demanded and its price, $w_j^{k',s}$, as well as the positive relationship between the demand for labor and the other factors of production and the share of this labor's type.

Most important for our purposes, equation (45) reveals two channels through which trade liberalization may affect the demand for labor. Both of these effects are channeled via the general equilibrium multilateral resistance indexes. The first impact of trade liberalization on the demand for labor is via the outward multilateral resistance, $\Pi_j^{k'}$. The relationship is inverse. Intuitively, a higher multilateral resistance for the producers in a given sector will translate (see equation 28) into lower factory gate prices, which, in turn, will lead to lower demand for labor in this industry. Importantly, since the the the outward multilateral resistance is a general equilibrium index, the labor demand $L_j^{k',s}$ can be affected by changes in trade costs of any country in the world.[10]

The second channel through which trade liberalization affects labor market outcomes is via the inward multilateral resistance, P_j^k. Once again, the relationship is inverse. To gain intuition we first recognize that P_j^k is the price of intermediate inputs. Thus, the explanation for the inverse relationship is that when intermediates become more expensive they will be substituted away from in favor of other factors including labor. Importantly, the impact of trade liberalization via this channel captures several general equilibrium relationships both at the country and at the sectoral level. At the extreme, this channel implies that a change in intrude costs in any sector and any country in the world may have potential impact of the demand for a specific type of labor in any other sector and other country in the world. The strength of such impact will, of course, depend on how strong are the specific input-output links in the world trade and production system.

3 From Theory to Empirics

This section demonstrates how system (25)-(33) can be used to quantify the impact of trade liberalization on the labor market. To that end, we follow the seminal work of Eaton and Kortum (2002) to characterize two extreme scenarios. One, where labor of each type and in each sector is taken as given. In this case all effects of trade liberalization will be channeled through wages. And one, where labor is mobile across sectors within a given labor type. In that case, the wage across sectors for each type will be equalized and changes in the wages we result in a reallocation of workers across sectors.

[10] While the net impact of changes in trade costs cannot be characterized analytically, empirical evidence and numerical simulations suggest that, in most cases, the impact on producer prices is positive for a country that liberalizes its trade policy and negative, via trade diversion effects, for a country that is left out of integration efforts that take place in the rest of the world. For further discussion on these general equilibrium links see Yotov et al. (2016).

Immobile Labor. Consider the immobile labor scenario first. Our general approach to quantify the impact of trade liberalization on labor market outcomes will be developed in two steps. First, we will estimate and/or calibrate some of the model parameters, e.g. trade costs and the elasticity of substitution, and calibrate the remaining (exogenous) parameters, e.g. the CES preference parameters, so that our model fits the data at initial factory-gate prices. This will be our baseline scenario. Then, we will 'shock' the system by changing the trade cost vector for a counterfactual scenario of our choice, and we will solve for the corresponding changes in factory-gate prices and other variables of choice.

We start by simplifying the structural system in order to decrease its dimensionality. Use the definition of $Y^k = \sum_i Y_i^k$, the expression for the outward multilateral resistance from equation (26), and the expression for the CES price aggregator to replace these three elements in the market clearing conditions system (28). Then simplify. System (25)-(33) transforms into:

$$\frac{Y_i^k}{\sum_i Y_i^k} = \sum_j \frac{(p_i^k \beta_i^k t_{ij}^k)^{1-\sigma^k}}{\sum_i (\beta_i^k p_i^k t_{ij}^k)^{1-\sigma^k}} \frac{E_j^k}{\sum_i Y_i^k}, \tag{34}$$

$$Y_i^k = p_j^k A_j^k \prod_{s=1}^{S} \left(L_j^{k,s}\right)^{\alpha_j^{k,s}} \prod_{k'=1}^{K} \left(M_j^{k',k}\right)^{\alpha_j^{k',k}}, \tag{35}$$

$$E_j^k = \psi^k \sum_{k'} \sum_s \alpha_j^{k',s} Y_j^{k'} + \sum_{k'} \alpha_j^{k,k'} Y_j^{k'}, \tag{36}$$

$$M_j^{k,k'} = \alpha_j^{k,k'} Y_j^{k'} / [\sum_i (\beta_i^k p_i^k t_{ij}^k)^{1-\sigma^k}]^{1/(1-\sigma^k)}. \tag{37}$$

Note that we have omitted the labor market equations. The reason is that the scenario with immobile labor is essentially an endowment scenario, where the change in wages will correspond one-to-one to the change in the value of production.

Replace the definition of intermediates from equation (37) in the production value function:

$$\frac{Y_i^k}{\sum_i Y_i^k} = \sum_j \frac{(p_i^k \beta_i^k t_{ij}^k)^{1-\sigma^k}}{\sum_i (\beta_i^k p_i^k t_{ij}^k)^{1-\sigma^k}} \frac{E_j^k}{\sum_i Y_i^k}, \tag{38}$$

$$Y_i^k = p_j^k A_j^k \prod_{s=1}^{S} \left(L_j^{k,s}\right)^{\alpha_j^{k,s}} \prod_{k'=1}^{K} (\alpha_j^{k,k'} Y_j^{k'} / [\sum_i (\beta_i^k p_i^k t_{ij}^k)^{1-\sigma^k}]^{1/(1-\sigma^k)})^{\alpha_j^{k',k}}, \tag{39}$$

$$E_j^k = \psi^k \sum_{k'} \sum_s \alpha_j^{k',s} Y_j^{k'} + \sum_{k'} \alpha_j^{k,k'} Y_j^{k'}. \tag{40}$$

Replace the definition of expenditure from (40) in the market clearing conditions (38) to obtain:

$$\frac{Y_i^k}{\sum_i Y_i^k} = \sum_j \frac{(p_i^k \beta_i^k t_{ij}^k)^{1-\sigma^k}}{\sum_i (\beta_i^k p_i^k t_{ij}^k)^{1-\sigma^k}} \frac{\psi^k \sum_{k'} \sum_s \alpha_j^{k',s} Y_j^{k'} + \sum_{k'} \alpha_j^{k,k'} Y_j^{k'}}{\sum_i Y_i^k}, \tag{41}$$

$$Y_i^k = p_j^k A_j^k \prod_{s=1}^{S} \left(L_j^{k,s}\right)^{\alpha_j^{k,s}} \prod_{k'=1}^{K} (\alpha_j^{k,k'} Y_j^{k'} / [\sum_i (\beta_i^k p_i^k t_{ij}^k)^{1-\sigma^k}]^{1/(1-\sigma^k)})^{\alpha_j^{k',k}}. \tag{42}$$

System (41)-(42) consists of $N \times K \times 2$ equations. As noted above, we will solve the system in two steps. First, we will solve it in the baseline scenario, where all factory-gate prices are equal to one. This is equivalent to treating our baseline values of output Y_i^k as endowments. Under this treatment, system (41)-(42) can be solved for the $N \times K$ CES share parameters β_i^k and for the $N \times K$ technology parameters A_j^k. This should complete the data and parameter requirements.[11] Then, in the second step, we solve the system again in response to a change in bilateral trade costs. This time, we solve for the $N \times K$ factory-gate prices and for the $N \times K$ values of output.

Mobile Labor. Now consider how the system will change if we allow for mobile labor.

[11] Note that in addition to the CES share parameters and the technology parameters, we will need data on (i) baseline output; (ii) data on trade costs, which require trade, policy, and gravity data; (iii) labor data, including quantities and shares; (iv) data on the CD preference parameters; and, (v) finally, we need data on the shares of intermediates.

First, we need to add the labor market equations.

$$\frac{Y_i^k}{\sum_i Y_i^k} = \sum_j \frac{(p_i^k \beta_i^k t_{ij}^k)^{1-\sigma^k}}{\sum_i (\beta_i^k p_i^k t_{ij}^k)^{1-\sigma^k}} \frac{\psi^k \sum_{k'} \sum_s \alpha_j^{k',s} Y_j^{k'} + \sum_{k'} \alpha_j^{k,k'} Y_j^{k'}}{\sum_i Y_i^k}, \tag{43}$$

$$Y_i^k = p_j^k A_j^k \prod_{s=1}^{S} \left(L_j^{k,s}\right)^{\alpha_j^{k,s}} \prod_{k'=1}^{K} (\alpha_j^{k,k'} Y_j^{k'} / [\sum_i (\beta_i^k p_i^k t_{ij}^k)^{1-\sigma^k}]^{1/(1-\sigma^k)})^{\alpha_j^{k',k}}, \tag{44}$$

$$L_j^{k',s} = \alpha_j^{k',s} Y_j^{k'} / w_j^s, \tag{45}$$

$$L_j^s = \sum_k L_j^{k,s}. \tag{46}$$

Note that we have expressed the wage equation as a labor demand equation, which also captures the fact that with mobile labor wages in each countries and for each type of labor are equalized. Replace $L_j^{k',s}$ from equation (45) into the production value function (44) and in the labor market clearing conditions (46):

$$\frac{Y_i^k}{\sum_i Y_i^k} = \sum_j \frac{(p_i^k \beta_i^k t_{ij}^k)^{1-\sigma^k}}{\sum_i (\beta_i^k p_i^k t_{ij}^k)^{1-\sigma^k}} \frac{\psi^k \sum_{k'} \sum_s \alpha_j^{k',s} Y_j^{k'} + \sum_{k'} \alpha_j^{k,k'} Y_j^{k'}}{\sum_i Y_i^k}, \tag{47}$$

$$Y_i^k = p_j^k A_j^k \prod_{s=1}^{S} \left(\alpha_j^{k',s} Y_j^{k'} / w_j^s\right)^{\alpha_j^{k,s}} \prod_{k'=1}^{K} (\alpha_j^{k,k'} Y_j^{k'} / [\sum_i (\beta_i^k p_i^k t_{ij}^k)^{1-\sigma^k}]^{1/(1-\sigma^k)})^{\alpha_j^{k',k}}, \tag{48}$$

$$L_j^s = \sum_k \alpha_j^{k',s} Y_j^{k'} / w_j^s. \tag{49}$$

As compared to the system with immobile labor, system (47)-(49) has $N \times S$ more equations and $N \times S$ more unknowns. Thus, it is exactly identified. The additional equations will pin down the wages for each type S in each of the N countries. This will ensure clearance at the labor market.

Quantification. We proceed in three steps in order to quantify the impact of trade liberalization on the labor market. First, we will obtain (estimate, calibrate, take from data, and/or borrow from the literature) all model parameters, which are needed to fit the model to the data in the baseline scenario. Then, we will 'shock' the system according to a counterfactual scenario of interest, e.g. the formation of a regional trade agreement between U.S. and U.K., and we will solve the model again. Finally, we will construct and analyze a series of indexes of interest that capture the impact of the hypothetical trade policy change.

Arguably, the first of the three steps is most challenging, both in terms of data requirements as well as in terms of computational challenges. We discuss those in turn. In order to fit the model to the data in the baseline scenario, we need values for the following parameters:

- **Bilateral trade costs, t_{ij}^k.** As is standard in the literature, bilateral trade costs are recovered from the structural gravity equation (25). Theory suggests trade separability, which means that we can recover the bilateral trade costs for each sector independently. There are two general approaches to obtain estimates of trade costs: estimation vs. calibration. Each approach has advantages and disadvantages and both approaches have been used widely in the literature.[12] Without loss of generality, and subject to the caveats of the estimation approach, will use standard gravity econometric techniques to recover the bilateral trade costs t_{ij}^k.

- **Shares of intermediates used in production, $\alpha_j^{k,k'}$.** The main analysis is performed with intermediate shares that do not vary across countries, i.e. $\alpha^{k,k'}$. One limitation of our analysis, again due to data availability, is that we only cover manufacturing industries. Thus, by construction, the shares of intermediates do not add

[12] Hundreds of papers have used the structural gravity equation to estimate the effects of various determinants of trade flows, cf. Head and Mayer (2014). The main downside of the estimation approach is the presence of an error term, which may carry systematic information about trade costs. Prominent methods to calibrate trade costs include Head and Ries (2001), Romalis (2007), Head, Mayer and Ries (2010), Novy (2013), and Caliendo and Parro (2015). The main downside of the calibration approach is that it does not allow for testing of causal effects and decomposition of the various components of trade costs, cf. Dawkins, Srinivasan and Whalley (2001) and Krugman (2011). Anderson, Larch and Yotov (2015*a*) propose a hybrid procedure to construct bilateral trade costs, which first estimates trade costs and trade elasticities from a properly specified empirical gravity equation, and then takes into account the information contained in the error term. This approach allows for a decomposition of the key trade cost components and enables to recover key elasticity parameters, while at the same time fitting the trade data perfectly by construction.

up to one. As a result, the total expenditure on goods from each sector in our data does not add to the total value of production, at delivered prices. Our solution is to construct a vector of residual intermediate share indexes a_m (of dimension $K \times 1$), which, when combined with the actual intermediate shares, ensures consistency in the model by equating the value of production and expenditure in each sector.

- **Shares of different labor types used in production, $\alpha_j^{k,s}$.** Similar to our assumption for common sectoral shares of intermediates across countries, we use labor-type shares that are also common across countries, i.e. $\alpha^{k,s}$. Construction of the labor-type using wage and employment data for multiple industries and countries is one of the unique features of our data and analysis.

- **Cobb-Douglas share parameters, ψ^k.** The Cobb-Douglas preference shares will be constructed directly from baseline data on sectoral output as:

$$\psi^k = \frac{Y^{k,0}}{\sum_k Y^{k,0}},$$

where $Y^{k,0} = \sum_j Y_j^{k,0}$. Note that, in principle, ψ^k can be allowed to vary in the baseline vs. counterfactual analysis. In our main experiments we keep ψ^k constant at the baseline level. However, allowing for changes in ψ^k due to changes in the value of production does not have qualitative and significant quantitative implications for our results.

- **Elasticity of substitution, σ^k.** Estimates of the elasticity of substitution can be recovered directly from gravity estimations when data on some direct price-shifter are available, e.g. data on tariffs. Such data were not available to us. Therefore, we follow the standard approach in the literature and we assign a common value of the elasticity of substitution $\sigma^k = 6$. We recognize and recommend that a rigorous policy analysis work should employ sector-specific estimates of the elasticity of substitution. However, given the demonstrative purposes of our analysis and, more importantly, in order to more clearly trace and decompose the key structural links in our model, we will use a common value for the trade elasticity of substitution across all sectors.

- **CES share parameters, β_i^k.** CES share parameters will be recovered from the market-clearing conditions in system (25)-(30).[13] In order to solve for the CES share parameters, we use data and parameters covering: Bilateral trade costs (t_{ij}^k); Shares of intermediates used in production ($\alpha^{k,k'}$); Cobb-Douglas share parameters (ψ^k); and baseline data on the sectoral value of production (Y_i^k). The CES share parameters in the baseline will be obtained and initial/baseline prices, i.e. p_j^k, $\forall j, k$. Finally, we discuss a couple of technical notes. First, we note that system (25)-(30) can only be solved up to a normalization for the the multilateral resistances, cf. Anderson and Yotov (2010*a*). Second, we note that, at initial prices, (25)-(30) can actually deliver the power transform of the CES share parameters $(\beta_i^k)^{1-\sigma}$ without the need to use a value for the trade elasticity of substitution. To see this, rewrite the market-clearing condition (28) by taking the $(1-\sigma)$ power transformation on both sides. The power transforms of the CES parameters is what we will recover and use throughout the analysis.

- **Capital-augmented technology values, A_j^k.** The capital-augmented technology values will be recovered from system (25)-(31) at initial prices. In addition to all data needed to recover the CES share parameters, the capital-augmented technology parameters will require data on (the power transforms of) the CES share parameters (β_i^k), as well as data on baseline labor allocations ($L_j^{k,s}$), and data on labor shares ($\alpha^{k,s}$).

The set of parameters $\{t_{ij}^k, \alpha^{k,k'}, \alpha^{k,s}, \psi^k, \sigma, \beta_i^k, A_j^k\}$ along with sectoral data on trade flows

[13] As noted earlier, the analysis can be performed without the need to recover the CES share parameters (as well as the capital-augmented technology values, A_j^k, which we discuss next). See for example Dekle, Eaton and Kortum (2007, 2008) and Caliendo and Parro (2015). If all other model parameters are the same, our approach and the methods from the above-mentioned papers deliver identical results.

X_{ij}^k, output Y_j^k, and labor shares $L_j^{k,s}$ will deliver the baseline solutions of system (25)-(33) both for the case of immobile labor as well as for the case of mobile labor. For given values of the parameters, a shock to the system (e.g. in the form of a trade policy change that will affect the vector of bilateral trade costs t_{ij}^k) will result into changes in consumer prices, producer prices, trade flows, output, expenditure, and labor allocations. The (percentage) difference between the new, counterfactual values of any variable of interest and its initial/baseline value will measure the effect of the trade policy change. We demonstrate in Section 6. Before that, we describe our data and we discuss the sectoral partial equilibrium gravity estimations that are used to construct the baseline vector of bilateral trade costs.

4 Data: Description and Sources

Our sample includes data on bilateral trade flows, gravity variables, production, and wages for 45 countries and 22 sectors in 2010. Industries are classified using ISIC rev. 3 industrial classification at the two-digit level. A list of all sectors in our sample, their IDs and corresponding ISIC codes appear in Table 1. A list of all countries in our sample and their corresponding ISO codes is included in Table 2. Next, in turn, we describe the data used to construct the key variables that we employ in our analysis, their sources, their advantages, and their limitations.

Labor Types. Critically for the analysis in our model, labor is disaggregated into three types, based on its level of education. The basis for the level of education is the International Standard Classification of Education (ISCED-97). The three levels of education distinguished by this paper are primary (first six years of schooling), secondary (years 7-12 of schooling), and tertiary (more than 12 years of schooling). Tertiary education includes Vocational Associate's programs and equivalents.

Wages. Wages for each country and type of labor come mostly from the Occupational Wages around the World (OWW) database, which uses data obtained by the ILO's October

Inquiry. OWW includes wages for 161 occupations in 171 countries. Each occupation in OWW is mapped to a ISCO-88 occupation code, which is in turn linked to a particular level of education as described in the ISCO-88 manual. For example occupation Chemical Engineer is linked to the tertiary level of education. The wages by education in each country are calculated by taking the average across all occupations with a given level of education. Wages are then converted to earnings using the conversion factors supplied in the OWW documentation. For countries in our dataset that do not report wages in the OWW database, we calculate wages by education using Mincerian regression estimated reported in the literature. We account for quality of education differences across countries. More details on this procedure can be found in Shikher (2015).

Labor shares. Labor shares in output for 18 industries were obtained from the OECD database of input-output tables for 43 countries. We use the average labor shares across countries for each industry. The 18 industries provided by the OECD database are based on the ISIC rev. 3 classification, but with some of the 22 two-digit industries aggregated together. In order to disaggregate the aggregated industries and obtain labor shares for all 22 industries, we use input-output tables for Germany and United Kingdom provided by Eurostat. These input-output tables include data for 22 two-digit ISIC rev. 3 industries. Labor shares in output described above are then combined with the shares of the three types of labor in total labor income. The shares of the three types of labor in total labor income are obtained using data from the World Bank Enterprise Surveys (WBES). More detail on labor data construction can be found in Shikher (2015).

Intermediate goods shares. Shares of each industry in total spending on intermediate goods by each industry were obtained from Eurostat's database of individual countries' input-output tables. Specifically, we use the average of the shares obtained from the intput-output tables of Germany and United Kingdon. These input-output tables include 22 manufacturing industries based on the ISIC rev. 3 classification.

Trade, Production, and Gravity Variables. Bilateral trade flows are sourced from COM-

TRADE. Sectoral production comes from the IndStat database of UNIDO. Missing values were estimated using nearby years and employment data. Data on various standard gravity variables, i.e., distance, common borders, common language, and colonial ties come from the CEPII's GeoDist database,[14] which includes data on these variables for 225 countries, and to the accompanying paper by Mayer and Zignago (2011) for detailed information on these commonly used gravity covariates. Data on regional trade agreements come from the Database on Economic Integration Agreements (EIAs) on Jeffey Bergstrand's website (www.nd.edu/ jbergstr). Baier and Bergstrand's EIA database categorizes bilateral EIA relationships from 1950-2005 for pairings of 195 countries using a multichotomous index. In our study, $RTA_{ij,t} = 1$ denotes a regional trade agreement between trading partners i and j in year $t$of any type (i.e. a free trade agreement, a customs union, common market, or economic union), or 0 otherwise. The main source of original data used to construct the Baier and Bergstrand's EIA database is the World Trade Organization (WTO).[15]

5 Gravity Estimation Results

This section delivers estimates of the vector of bilateral trade costs, which are needed for the counterfactual analysis. In addition, the estimation analysis will enable us to validate the underlying trade data sample and will generate some useful and interesting policy insights about the direct impact of trade costs and their variation across sectors. In order to estimate trade costs, we set up the following econometric model, which corresponds to the structural gravity equation (25) from our theoretical system:[16]

$$\begin{aligned} X_{ij}^k &= \exp[\beta_0^k + \beta_1^k \ln DIST_{ij} + \beta_2^k CNTG_{ij} + \beta_3^k LANG_{ij} + \beta_4^k CLNY_{ij}] \times \\ & \quad \exp[\beta_5^k BRDR_{ij} + \beta_6^k RTA_{ij} + \eta_{i,t}^k + \theta_{j,t}^k] \times \epsilon_{ij,t}^k, \qquad \forall k. \end{aligned} \tag{50}$$

[14]http://www.cepii.fr/cepii/en/bdd_modele/presentation.asp?id=6

[15]The WTO preferential trade agreements data are available at http://www.ewf.uni-bayreuth.de/en/research/RTA-data/index.html.

[16]Separability of structural gravity allows us to estimate the empirical gravity model for every sector.

Here, as defined previously, X_{ij}^k denotes the nominal bilateral trade flows from exporter i to importer j in sector k, and we have used the following observable or constructed variables to proxy for the unobservable sectoral bilateral trade costs t_{ij}^k. $\ln DIST_{ij}$ is the logarithm of bilateral distance between trading partners i and j. $CNTG_{ij}$, $LANG_{ij}$ and $CLNY_{ij}$ capture the presence of contiguous borders, common language and colonial ties, respectively. $BRDR_{ij}$ as a border dummy variable equal to 1 when $i \neq j$ and zero elsewhere, which captures the effect of crossing the international border by shifting up internal trade, all else equal. Finally, RTA_{ij} is an indicator variable that takes a value of one for the presence of regional trade agreements in our sample. It is equal to one when trading partners i and j are partners of the same RTA, and it is equal to zero otherwise.

Following the recommendations of Santos Silva and Tenreyro (2006), we estimate specification (50) with the Poisson Pseudo Maximum Likelihood (PPML) estimator, which accounts for heteroskedasticity in trade data and takes advantage of the information that is contained in the zero trade flows because it is estimated in multiplicative form. Finally, we use exporter fixed effects, $\eta_{i,t}^k$, and importer fixed effects, $\theta_{j,t}^k$ to control for the unobservable multilateral resistances as well as for any other observable or unobservable country feature (e.g. size) on the importer and on the exporter side.

We use specification (50) to obtain gravity estimates for each of the 22 sectors in our sample. Our findings are reported in Tables 3–5. We start in column (1) of Table 3 with estimates for aggregate manufacturing, then each of the following columns in this table as well as all columns in Tables 4–5 report gravity estimates for each individual sector. Overall, our estimates are consistent with existing counterparts from the literature, which usually are obtained at the aggregate level. For a benchmark reference and comparisons, we refer to the meta analysis gravity estimates from Table 4 of Head and Mayer (2014).

Several findings stand out based on the estimates from Tables 3–5. First, as expected, we find that distance is a significant impediment to trade. Without any exception, all estimates of the effects of distance are negative, highly statistically significant and with magnitudes that are comparable to estimates from the literature. The estimate of the effect of distance for total manufacturing (see column (1) of Table 3) is not statistically different from, and in fact almost identical to, the corresponding meta analysis estimate of the distance effects in Head and Mayer (2014). We also find significant (but intuitive and within reasonable bounds) variation in the distance effects. The smallest estimate is -0.465 (std.err. 0.117) for Light Transport Equipment and the largest estimate is -1.336 (std.err. 0.176) for sector Petroleum and Coal products. We find the variation of the estimates of the effects of distance mostly intuitive and mainly reflecting transportation costs.

All else equal, sharing a common border promotes trade. This is confirmed by our estimates of the effects of contiguity ($CNTG_{ij}$). Twenty one of the twenty two estimates on $CNTG$ are positive, and sixteen of them are statistically significant. The average manufacturing estimate from column (1) of Table 3) is not statistically different from the corresponding meta analysis estimate of the distance effects in Head and Mayer (2014), and the latter falls comfortably within the distribution of $CNTG$ estimates that we obtain across the different sectors in our sample. As is well documented in the literature, sharing a common language promotes bilateral trade, all else equal. We confirm this regularity with twenty positive estimates on $LANG$, and most of them being statistically significant. Once again, our average manufacturing estimate for the effect of $LANG$ from column (1) of Table 3) does not seem to be statistically different from the corresponding meta analysis estimate in Head and Mayer (2014), and the latter is within the distribution of $CNTG$ estimates that we obtain across the different sectors in our sample.

We also obtain mostly positive and significant estimates of the effects of colonial ties. However, the results are weaker as compared to the findings for contiguity and for language. Thus, for example, our average manufacturing estimate of the effects of $CLNY$ is not statistically significant and is significantly smaller as compared to the corresponding estimate in Head and Mayer (2014). This result is consistent with the estimates from Anderson and Yotov (2010*b*), who explain it with a decrease of the political importance of colonial relationships in favor of comparative advantage forces. It should also be noted that about a quarter of our $CLNY$ estimates are positive, statistically significant and comparable to the meta analysis estimate from Head and Mayer (2014).

The most robust finding from Tables 3–5 is that international borders have large and strong effects. With only one exception, we obtain large, negative, and statistically significant estimates of the effects of $BRDR_{ij}$. The only insignificant border estimate that we obtain is for Other Manufacturing and, due to the nature of this industry, we cannot offer an intuitive explanation for this result. The average $BRDR$ estimate implies that, all else equal, international trade is about 10 times smaller than intra-national trade. This estimate is significantly smaller as compared to the famous border estimate of McCallum (1995) but it is still very large, suggesting that there are still very large potential gains to be realized from trade liberalization. The variation of the $BRDR$ estimates across sectors makes sense for the most part. Thus, for example, the largest border estimate is for Tobacco (-6.426, std.err. 0.575) and the smallest, but still sizable, is for Medical Equipment (0.619, std.err. (0.286). We find both of these estimates, as well as the overall variation of the $BRDR$ estimates to be quite intuitive with respect to the nature of the products within a given sector.

Finally, and as expected, we find that forming a regional trade agreement promotes international trade. Eighteen of the RTA estimates that we obtain are positive and fourteen of them are statistically significant.[17] In terms of magnitude, the average RTA estimate from column (1) of Table 3) is smaller than the meta analysis number in Head and Mayer (2014).[18] However, the variation of the RTA estimates across the sectors in our sample is wide and many of them are readily comparable to existing estimates from the literature, e.g. those from Baier and Bergstrand (2007), Anderson and Yotov (2016), and Baier, Yotov and Zylkin (2016). The largest effect that we obtain is for Tobacco (1.971, std.err. 0.373) and the

[17]The only negative and statistically significant RTA estimate is for sector Other Manufacturing. The same sector for which our estimate of the effect of international borders was not significant.

[18]A possible explanation for the small RTA estimate that we obtain here for aggregate manufacturing is the fact that we do not control for possible endogeneity of regional trade agreements. Availability of panel data would have allowed us to implement the average treatment effect methods of Baier and Bergstrand (2007) in order to account for potential endogeneity of RTAs.

smallest positive and significant estimate that we obtain is for Fabricated Metal Products (0.283, std.err. 0.127). An additional advantage of the sectoral RTA estimates is that they are less susceptible to endogeneity issues since it is less likely that considerations for specific sectors may influence the decision to sign an agreement at the country level.

Overall, we find the gravity estimates that we obtain in this section to be intuitive and in accordance with estimates that have been validated by the existing literature. Therefore, we are comfortable using our estimates to construct bilateral trade costs and to use them to perform the counterfactual analysis in the next section.

6 On the Effects of U.S–U.K. Trade Liberalization

This section demonstrates how our framework can be employed to evaluate the effects of trade liberalization on labor market outcomes with heterogeneous workers. For demonstrative purposes we simulate a hypothetical (but also likely to take place) trade liberalization scenario between the United States and Great Britain. Consistent with our gravity estimation analysis and with the intuition that RTAs stimulate international trade beyond simply removing tariffs, we use an RTA estimate to reduce trade costs between the two countries.

Given the demonstrative purpose of the analysis in this section, we choose to employ a common RTA estimate, i.e. an RTA effect that exerts the same initial partial effect in all sectors. This way, we will ensure that none of the heterogeneous effects that we obtain are driven by the initial RTA effects and we will be able to better judge the validity and performance of our framework. In addition, instead of employing the average manufacturing RTA estimate from column (1) of Tables 3, which, as discussed earlier, may be subject to endogeneity critiques, we rely on the RTA estimate of 0.76 from the original work of Baier and Bergstrand (2007). We view the RTA estimate from Baier and Bergstrand (2007) as appropriate because it falls comfortably in the middle of the distribution of our own sector-specific RTA estimates from Tables 3–5. Under these assumptions, our baseline trade costs are constructed as:

$$\left(t_{ij}^{k\ 1-\sigma}\right)^{bsln} = \exp[\beta_1^k LN\_DIST_{ij} + \beta_2^k CNTG_{ij} + \beta_3^k LANG_{ij}] \times \exp[\beta_4^k CLNY_{ij} + \beta_5^k BRDR_{ij} + \beta_6^k RTA_{ij}], \quad (51)$$

where, "$bsln$" stands for baseline scenario and all other variables are defined before. And the counterfactual trade costs are constructed as:

$$\left(t_{ij}^{k\ 1-\sigma}\right)^{ctrf} = \left(t_{ij}^{k\ 1-\sigma}\right)^{bsln} \times \exp[0.76 \times RTA\_UK\_US_{ij}], \quad (52)$$

where, "$ctrf$" stands for counterfactual scenario, and $RTA\_UK\_US_{ij}$ is an indicator variable that is equal to one for trade between UK and US, and it is equal to zero otherwise.

With these trade costs and with all other data and parameters, we proceed to solve our model in the baseline and in the counterfactual scenario. Due to the rich dimensionality of our counterfactual indexes data set, we had to make presentation choices. We decided to present two sets of results, which are central to the analysis.[19] These include: (i) a series of cross-section indexes at the country level that are obtained as aggregates across all sectors, and which are reported in Table 6; and (ii) a series of indexes for the US, which are reported in Table 7. The cross-country indexes would enable us to establish the validity of our methods by comparing them with results from previous studies, while the US-specific sectoral results will enable us to discuss sectoral dimension of our findings. The latter is important since one of our main contributions is to allow for different labor types and we expect to see action across the sectoral dimension. In the main text we report the results that are based on the scenario with mobile labor. Corresponding estimates from the scenario with immobile labor are included in the Appendix. Finally, all counterfactual indexes that we present and discuss in this report are constructed as percentage changes:

[19] The complete set of all counterfactual indexes are available by request.

$$\%\Delta IND = 100 \times \frac{IND^{ctrf} - IND^{bsln}}{IND^{bsln}}, \tag{53}$$

where: IND can be any index of interest.

We start with an analysis of the cross-country estimates from Table 6. Column (1) of this table reports percentage changes in total exports for each country in our sample. To construct the percentage changes between the baseline and the counterfactual exports for each country, we simply calculate total exports in each scenario as the sum of bilateral exports (excluding domestic sales):

$$X_i = \sum_{j \neq i} X_{ij}, \tag{54}$$

where, as defined earlier, X_{ij} denotes nominal bilateral trade flows at delivered prices.

The results are intuitive and with reasonable magnitudes. Britain gains the most, about 12 percent increase in total exports. US follows with a much smaller increase in total exports of about 3 percent. The rest of the world is affected negatively. Trade diversion is a natural explanation for the smaller exports in the rest of the world. We note that, in principle, it is possible that the exports of some countries increase due to the UK-US agreement. The intuition is that in the GE scenario UK and US will become richer/larger and they will buy more from all trading partners. However, we do not see such strong size effects here. The biggest "losers", in terms of decreased exports, are the Dominican Republic, Ireland, and Mexico. Close trade ties with the liberalizing nations explains the trade diversion patterns.

Next, we turn to the results in column (2) of Table 6, which reports the percentage changes in the IMR indexes per country. Consistent with theory, these indexes can be interpreted as percentage changes in consumer prices. In order to aggregate the sectoral IMRs to the country level, we follow Anderson and Yotov (2016) to define:

$$P_i = \exp\left(\sum_k \alpha_k \ln P_i^k\right). \tag{55}$$

The effects on the consumers in the world from column (2) of Table 6 are constructed as the percentage difference between the aggregate IMRs from (55) in the counterfactual scenario and the corresponding indexes in the baseline scenario.

The percentage changes in consumer prices from column (1) make intuitive sense. Overall the effects on consumer prices are small. Britain experiences the largest decrease in consumer prices of 0.7 percent. US follows with a much smaller decrease of 0.12 percent. The natural explanation for the differences in the price changes between the two liberalizing partners is country size. The effects on consumer prices in outside countries are really small. We observe some positive and some negative price effects in the rest of the world. It is tempting to interpret the negative indexes as price decreases in the rest of the world due to the UK-US agreement (e.g. due to increased production efficiency in the liberalizing countries, which is passed on consumers everywhere in the world). However, we caution the reader that the IMRs for all countries are constructed relative to the German IMR and, therefore, should be interpreted accordingly.

Finally, columns (3) and (4) of Table 6 report percentage changes in nominal GDP and real GDP, respectively. Nominal GDP is constructed by adding up all sectoral values of production for each country:

$$GDP_i = \sum_k Y_i^k = \sum_k p_i^k q_i^k, \tag{56}$$

and real GDP is defined as the ratio between nominal GDP and the aggregate consumer price index:

$$RGDP_i = \frac{GDP_i}{P_i} = \frac{\sum_k p_i^k q_i^k,}{exp(\sum_k \alpha_k \ln P_i^k)}. \tag{57}$$

The effects on nominal and real GDP are qualitatively identical to each other. Therefore, we only focus on the real GDP effects. As expected, the main gains are concentrated in the liberalizing countries. Our estimates imply a 3.6 percent gain in real GDP for the UK and a smaller but still positive and sizable gain of 1 percent for the US. All outside countries register real GDP losses, which vary intuitively with the larger losses for countries that are more closely related to the liberalizing nations. It should also be noted that the effects on the outside world is relatively small. The largest negative impact of -0.42 percent is for the Dominican Republic, and the average effect across all other countries is -0.11 percent. In sum, we view the aggregate GE estimates of the effects of the UK-US agreement as plausible, both for the member and for the non-member countries. This is encouraging evidence and represents a validation of sorts of our methods. Therefore, we are more confident to proceed with the sectoral analysis of the hypothetical impact of the UK-US on the United States.

The sectoral estimates are reported in Table 7.[20] Column (1) of Table 7 reports percentage changes in US trade by sector. According to our estimates, the largest increase in US exports will be observed in Manufacture of wood and of products of wood and cork, except furniture, followed by Manufacture of machinery and equipment and Manufacture of radio, television and communication equipment and apparatus. The smallest increase will be observed in Manufacture of tobacco products and Manufacture of wearing apparel; dressing and dyeing of fur. Interestingly, we document a decrease in US exports in the industry Other Manufacturing. This is due to the GE forces in our model, in combination with very strong positive effects for UK exports in this industry (see Table 8 of the Appendix).

Column (2) of Table 7 reports effects on consumer prices at the sectoral level. Overall, the effects on consumer prices are small.[21] The largest impact (a decrease of 1.4 percent relative to consumer prices in Germany) is on the prices in the industry Other Manufacturing. This result can be explained with the surge in imports from UK in this industry. The next two categories with comparably large decreases in relatively prices are Tanning and dressing of leather; manufacture of luggage, footwear, etc. (0.52 percent) and Manufacture of office, accounting and computing machinery (0.28 percent). Both of these sectors experience a significant increase in British exports to US, which explains the results for consumer prices.

[20]Sectoral estimates for all countries are available by request. We report estimates for the UK in Table 8 of the Appendix.

[21]We remind the reader that the IMR indexxes are relative to the corresponding effects on consumers in Germany, which is our reference country.

We also observe some positive (relative) price changes, e.g. in Manufacture of coke, refined petroleum products and nuclear fuel, Manufacture of wood and of products of wood and cork, except furniture, and Manufacture of paper and paper products. The explanation for these results is that US exports increase the most in those sectors and, therefore, when faced with more lucrative opportunities abroad, the US producers bid up domestic prices.

Columns (3) and (4) of Table 7 report percentage changes in nominal GDP and real GDP at the sectoral level, respectively. The results in the two columns are qualitatively identical and, therefore, we focus our analysis on the nominal GDP effects from column (3). The value of production will increase in most US sectors. The five sectors that will gain the most in terms of increase in the value of their production include Manufacture of radio, television and communication equipment and apparatus, Manufacture of textiles, Manufacture of wood and of products of wood and cork, except furniture, and Manufacture of paper and paper products, and Manufacture of rubber and plastics products. The value of production will fall in four US sectors, including Tanning and dressing of leather; manufacture of luggage, footwear, etc., Manufacture of furniture; manufacturing n.e.c., Manufacture of office, accounting and computing machinery, and Manufacture of wearing apparel; dressing and dyeing of fur. These results are consistent with our findings for the changes in US sectoral trade, as well as with the numbers for the impact on the UK economy, which are reported in Table 8 of the Appendix.

We finish our analysis with a discussion on the effects on labor in the US. The relevant indexes are reported in columns (5)-(7) of Table 7 and capture the effects on labor with primary education, labor with secondary education, and labor with higher education, respectively. Two main findings stand out from our estimates. First, we find that the number of workers employed in some sectors will increase, while the number of workers employed in other sectors will fall.[22] The sectors that will accept the largest number of workers are

[22] We remind the reader that in this scenario wages for each type across the different industries in the United States are equalized since workers will relocate to the industries with higher wages. Our estimates reveal that wages for each type or labor will increase by about 0.7 percent.

Manufacture of radio, television and communication equipment and apparatus, Manufacture of textiles, Manufacture of wood and of products of wood and cork, except furniture, and Manufacture of paper and paper products, and Manufacture of rubber and plastics products. This is expected since these are exactly the sectors where producer prices and production will increase the most. Our estimates suggest that the number of workers will actually decrease in more than half of the US sectors. As expected, the biggest negative impact on labor will be felt in the sectors where exports decrease (or increase the least). These sectors include Tanning and dressing of leather; manufacture of luggage, footwear, etc., Manufacture of furniture; manufacturing n.e.c., Manufacture of office, accounting and computing machinery, and Manufacture of wearing apparel; dressing and dyeing of fur.

Second, despite the fact that we are considering a hypothetical trade liberalization scenario between two very similar economies, we do find some small differential effects on labor across the different types. Specifically, a comparison between the effects on labor with primary and with higher education reveals that the number of workers with the highest level of education in our sample will increase more in the industries that hire more workers and will decrease less in the industries that let workers go. All else equal, this points to potential increase in income inequality in the US even from trade liberalization within a very similar developed partner such as the UK.

The corresponding estimates for the United Kingdom, which are reported in Table 8 of the Appendix, reveal the following. First, the impact on labor in the UK will be stronger. Relative size between the liberalizing partners is a natural explanation for this result. Second, the differential impact of the UK-US agreement on the different types of workers is more pronounced in the UK. Third, the UK-US agreement would lead to a stronger negative impact and to a weaker positive effect on the workers with the highest education as compared to the less educated workers, thus pointing to a potential decrease in income inequality in the UK in response to the UK-US RTA. The heterogeneity in the effects on labor that we obtained and the intuitive variation across sectors and labor types demonstrates that the theoretical framework developed here is effective in capturing the impact of trade liberalization on heterogeneous labor, and we expect that the heterogeneous effects across labor types will be even more pronounced and more heterogeneous for an agreement between a developed and a developing country.

7 Conclusion

We augment a general equilibrium gravity model with multiple types of workers distinguished by education. We consider workers with primary, secondary, and tertiary levels of education. This model allows us to study the effects of trade policies on wage inequality.

We present the model and explain how trade policy shocks are transmitted to labor markets. We then use data for 45 countries and 22 industries to estimate model parameters. We show how the model can be used in trade policy analysis by considering a regional trade agreement (RTA) between the United States and United Kingdom. The results show that such an agreement would have heterogeneous effects on different worker types in different countries. Our results point to a potential increase in income inequality in the U.S. and decrease in income inequality in the U.K as the result of this RTA.

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Table 1: Sectoral Coverage

(1) Sector ID	(2) ISIC Codes	(3) Sector Lable	Sector Description
1	15	Food	Manufacture of food products and beverages
2	16	Tobacco	Manufacture of tobacco products
3	17	Textiles	Manufacture of textiles
4	18	Apparel	Manufacture of wearing apparel; dressing and dyeing of fur
5	19	Leather	Tanning and dressing of leather; manufacture of luggage, footwear, etc.
6	20	Wood	Manufacture of wood and of products of wood and cork, except furniture
7	21	Paper	Manufacture of paper and paper products
8	22	Printing	Publishing, printing and reproduction of recorded media
9	23	Petroleum	Manufacture of coke, refined petroleum products and nuclear fuel
10	24	Chemicals	Manufacture of chemicals and chemical products
11	25	Rubber	Manufacture of rubber and plastics products
12	26	Minerals	Manufacture of other non-metallic mineral products
13	27	Metals_A	Manufacture of basic metals
14	28	Metals|_B	Manufacture of fabricated metal products, except machinery and equipment
15	29	Machinery_A	Manufacture of machinery and equipment n.e.c.
16	30	Machinery_B	Manufacture of office, accounting and computing machinery
17	31	Electrical_A	Manufacture of electrical machinery and apparatus n.e.c.
18	32	Electrical_B	Manufacture of radio, television and communication equipment and apparatus
19	33	Medical	Manufacture of medical, precision and optical instruments, watches and clocks
20	34	Transport_A	Manufacture of motor vehicles, trailers and semi-trailers
21	35	Transport_B	Manufacture of other transport equipment
22	36	Other	Manufacture of furniture; manufacturing n.e.c.

Notes: This table lists the Sector IDs, in column (1), the sector ISIC codes,, in column (2), the corresponding sector labels that are used in the paper, in column (3), and description of the sectors, in column (4), for the industries in our sample.

Table 2: Country Coverage

ISO Country Code	Country Name
DZA	Algeria
ARG	Argentina
AUS	Australia
AUT	Austria
BEL	Belgium
BRA	Brazil
BGR	Bulgaria
CAN	Canada
CHN	China
CZE	Czech Republic
DNK	Denmark
DOM	Dominican Republic
EGY	Egypt, Arab Rep.
FIN	Finland
FRA	France
DEU	Germany
GRC	Greece
HUN	Hungary
IND	India
IDN	Indonesia
IRL	Ireland
ITA	Italy
JPN	Japan
KOR	Korea
LTU	Lithuania
MYS	Malaysia
MEX	Mexico
NLD	Netherlands
NOR	Norway
PHL	Philippines
POL	Poland
PRT	Portugal
ROM	Romania
RUS	Russia
SVK	Slovakia
ESP	Spain
SWE	Sweden
CHE	Switzerland
OAS	Taiwan
THA	Thailand
TUR	Turkey
UKR	Ukraine
GBR	United Kingdom
USA	United States
VNM	Vietnam

Notes: This table lists the ISO Country Codes, in column (1), and the Country Names, in column (2), for the countries in our sample.

Table 3: Sectoral Gravity Estimates I, PPML, 2010

	(1) Manuf	(2) Food	(3) Tobacco	(4) Textiles	(5) Apparel	(6) Leather	(7) Wood	(8) Paper
LN_DIST	-0.869	-0.807	-0.926	-1.011	-1.097	-0.879	-0.891	-1.017
	(0.056)**	(0.074)**	(0.180)**	(0.115)**	(0.090)**	(0.102)**	(0.107)**	(0.084)**
CNTG	0.354	0.582	0.516	0.026	0.467	0.320	1.071	0.538
	(0.154)*	(0.192)**	(0.293)$^{+}$	(0.257)	(0.168)**	(0.160)*	(0.157)**	(0.166)**
LANG	0.306	0.441	0.031	0.191	0.375	-0.123	0.193	0.190
	(0.117)**	(0.155)**	(0.377)	(0.226)	(0.167)*	(0.175)	(0.164)	(0.127)
CLNY	0.069	0.166	0.475	0.090	0.005	-0.003	-0.183	0.018
	(0.134)	(0.140)	(0.462)	(0.232)	(0.216)	(0.194)	(0.168)	(0.180)
BRDR	-2.391	-3.845	-6.426	-2.472	-2.363	-2.069	-3.524	-3.031
	(0.166)**	(0.195)**	(0.575)**	(0.314)**	(0.251)**	(0.296)**	(0.345)**	(0.232)**
RTA	0.184	0.621	1.971	0.555	0.318	-0.181	0.133	0.482
	(0.104)$^{+}$	(0.098)**	(0.373)**	(0.154)**	(0.145)*	(0.168)	(0.169)	(0.118)**
N	2116	2116	2116	2116	2116	2116	2116	2116

Notes: This table reports sectoral gravity estimates that are obtained with the PPML estimator and exporter and importer fixed effects, which are omitted for brevity. The first column reports estimates for aggregate manufacturing and each of the following columns report estimates for individual sectors. Standard errors are clustered by country-pair and are reported in parentheses. $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

Table 4: Sectoral Gravity Estimates II, PPML, 2010

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
	Printing	Petroleum	Chemicals	Rubber	Minerals	Metals_A	Metals_B	Machinery_A
LN_DIST	-0.919	-1.336	-0.892	-0.972	-1.040	-0.938	-0.837	-0.716
	(0.086)**	(0.176)**	(0.071)**	(0.089)**	(0.074)**	(0.100)**	(0.084)**	(0.067)**
CNTG	0.566	0.745	0.072	0.502	0.410	0.237	0.621	0.454
	(0.183)**	(0.297)*	(0.166)	(0.191)**	(0.177)*	(0.267)	(0.163)**	(0.167)**
LANG	0.810	0.590	0.346	0.265	0.329	0.380	0.124	0.348
	(0.168)**	(0.241)*	(0.156)*	(0.140)+	(0.147)*	(0.180)*	(0.166)	(0.153)*
CLNY	0.353	-0.046	0.464	0.013	0.462	0.659	0.138	0.196
	(0.186)+	(0.326)	(0.164)**	(0.163)	(0.230)*	(0.175)**	(0.151)	(0.135)
BRDR	-3.257	-4.996	-1.776	-3.091	-3.336	-2.835	-3.411	-2.218
	(0.270)**	(0.494)**	(0.203)**	(0.226)**	(0.199)**	(0.243)**	(0.238)**	(0.182)**
RTA	0.327	1.048	0.460	0.514	0.151	0.749	0.283	0.087
	(0.153)*	(0.254)**	(0.120)**	(0.115)**	(0.124)	(0.134)**	(0.127)*	(0.120)
N	2116	2116	2116	2116	2116	2116	2116	

Notes: This table reports sectoral gravity estimates that are obtained with the PPML estimator and exporter and importer fixed effects, which are omitted for brevity. Standard errors are clustered by country-pair and are reported in parentheses. $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

Table 5: Sectoral Gravity Estimates III, PPML, 2010

	(1) Machinery_B	(2) Electrical_A	(3) Electrical_B	(4) Medical	(5) Transport_A	(6) Transport_B	(7) Other
LN_DIST	-1.009	-0.965	-0.780	-0.888	-0.798	-0.465	-1.105
	(0.161)**	(0.080)**	(0.078)**	(0.089)**	(0.138)**	(0.117)**	(0.137)**
CNTG	0.198	0.304	0.038	-0.130	0.517	1.160	0.500
	(0.349)	(0.246)	(0.219)	(0.145)	(0.258)*	(0.460)*	(0.197)*
LANG	0.294	0.183	0.478	0.457	0.410	-0.145	0.208
	(0.413)	(0.209)	(0.165)**	(0.157)**	(0.294)	(0.332)	(0.219)
CLNY	-1.061	0.067	-0.175	-0.157	-0.376	0.589	0.373
	(0.465)*	(0.164)	(0.279)	(0.204)	(0.246)	(0.348)+	(0.251)
BRDR	-2.597	-1.598	-1.552	-0.619	-2.636	-2.700	-0.086
	(0.457)**	(0.212)**	(0.210)**	(0.286)*	(0.365)**	(0.357)**	(0.439)
RTA	0.123	0.170	0.331	-0.215	1.038	-0.090	-0.740
	(0.232)	(0.142)	(0.146)*	(0.177)	(0.204)**	(0.184)	(0.235)**
N	2116	2116	2116	2116	2116	2116	2116

Notes: This table reports sectoral gravity estimates that are obtained with the PPML estimator and exporter and importer fixed effects, which are omitted for brevity. Standard errors are clustered by country-pair and are reported in parentheses. $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

Table 6: Cross-country GE Effects of the UK-US RTA, Mobile Labor

ISO	NAME	%Δ Trade	%Δ CPI	%Δ GDP	%Δ Real GDP
ARG	Argentina	-0.282	0.0001	-0.089	-0.089
AUS	Australia	-0.174	0.0003	-0.031	-0.032
AUT	Austria	-0.350	-0.0007	-0.115	-0.114
BEL	Belgium	-0.344	-0.0002	-0.108	-0.108
BGR	Bulgaria	-0.258	0.0001	-0.072	-0.072
BRA	Brazil	-0.370	-0.0011	-0.121	-0.119
CAN	Canada	-0.392	0.0022	-0.083	-0.085
CHE	Switzerland	-0.421	-0.0006	-0.132	-0.131
CHN	China	-0.212	-0.0006	-0.068	-0.068
CZE	Czech Republic	-0.321	-0.0002	-0.100	-0.0100
DEU	Germany	-0.358	0.000	-0.102	-0.102
DNK	Denmark	-0.331	0.0001	-0.099	-0.100
DOM	Dominican Republic	-1.106	0.0003	-0.421	-0.422
DZA	Algeria	-0.321	0.0002	-0.106	-0.106
EGY	Egypt, Arab Rep.	-0.230	-0.0003	-0.051	-0.051
ESP	Spain	-0.320	0.0001	-0.103	-0.103
FIN	Finland	-0.429	-0.0002	-0.143	-0.143
FRA	France	-0.361	0.0002	-0.117	-0.117
GBR	United Kingdom	11.980	-0.692	2.889	3.606
GRC	Greece	-0.258	-0.0001	-0.076	-0.076
HUN	Hungary	-0.345	-0.0005	-0.104	-0.103
IDN	Indonesia	-0.290	-0.001	-0.094	-0.093
IND	India	-0.192	-0.0003	-0.0489	-0.0485
IRL	Ireland	-0.851	0.0026	-0.309	-0.311
ITA	Italy	-0.350	-0.0004	-0.106	-0.106
JPN	Japan	-0.299	-0.0012	-0.096	-0.095
KOR	Korea	-0.300	-0.0011	-0.104	-0.103
LTU	Lithuania	-0.367	-0.0002	-0.124	-0.124
MEX	Mexico	-0.590	0.0001	-0.177	-0.177
MYS	Malaysia	-0.291	-0.0011	-0.096	-0.092
NLD	Netherlands	-0.431	-0.0003	-0.141	-0.141
NOR	Norway	-0.407	0.0002	-0.142	-0.143
OAS	Taiwan	-0.287	-0.0009	-0.092	-0.091
PHL	Philippines	-0.285	-0.0005	-0.087	-0.088
POL	Poland	-0.344	-0.0006	-0.114	-0.113
PRT	Portugal	-0.341	0.0001	-0.108	-0.108
ROM	Romania	-0.299	0.0001	-0.091	-0.091
RUS	Russia	-0.260	-0.0003	-0.077	-0.073
SVK	Slovakia	-0.348	-0.0002	-0.112	-0.112
SWE	Sweden	-0.394	-0.0001	-0.124	-0.124
THA	Thailand	-0.311	-0.001	-0.102	-0.101
TUR	Turkey	-0.257	-0.0002	-0.067	-0.067
UKR	Ukraine	-0.233	-0.0001	-0.064	-0.064
USA	United States	3.004	-0.118	0.789	0.908
VNM	Vietnam	-0.313	-0.0005	-0.111	-0.110

Notes: This table reports the GE effects of a hypothetical RTA between UK and US on all countries in our sample. The simulated scenario allows for labor to be mobile across sectors. Column (1) reports effects on total exports. Column (2) reports effects on consumer prices. Columns (3) and (4) report estimates for nominal and real GDP. See text for further details.

Table 7: GE Effects of the UK-US RTA on the US Economy, Mobile Labor

SECTOR LABEL	SECTOR ID	ISIC	%Δ Trade	%Δ CPI	%Δ Income	%Δ Real Income	%Δ L_Prim	%Δ L_Sec	%Δ L_Ter
Food	1	15	3.650	-0.010	1.010	1.130	0.210	0.240	0.240
Tobacco	2	16	0.200	-0.010	0.300	0.420	-0.480	-0.460	-0.460
Textiles	3	17	5.740	0.010	1.710	1.830	0.910	0.930	0.930
Apparel	4	18	1.160	-0.230	-0.290	-0.170	-1.070	-1.050	-1.050
Leather	5	19	1.360	-0.520	-1.800	-1.690	-2.570	-2.550	-2.550
Wood	6	20	7.620	0.020	1.640	1.760	0.840	0.850	0.860
Paper	7	21	4.810	0.020	1.620	1.740	0.820	0.840	0.840
Printing	8	22	1.960	-0.050	0.740	0.860	-0.0500	-0.0300	-0.0300
Petroleum	9	23	1.610	0.030	0.770	0.890	-0.0300	-0.0100	0.000
Chemicals	10	24	2.370	-0.140	0.540	0.650	-0.260	-0.240	-0.230
Rubber	11	25	4.530	0.000	1.160	1.280	0.370	0.390	0.390
Minerals	12	26	3.680	-0.030	0.670	0.780	-0.120	-0.100	-0.100
Metals_A	13	27	6.100	-0.010	0.970	1.090	0.170	0.200	0.200
Metals|_B	14	28	1.240	-0.060	0.440	0.560	-0.350	-0.330	-0.330
Machinery_A	15	29	4.480	-0.190	0.550	0.670	-0.240	-0.220	-0.220
Machinery_B	16	30	2.820	-0.280	-0.560	-0.440	-1.340	-1.320	-1.320
Electrical_A	17	31	3.020	-0.170	0.450	0.570	-0.330	-0.310	-0.310
Electrical_B	18	32	6.820	-0.050	2.020	2.140	1.220	1.240	1.240
Medical	19	33	3.100	-0.190	1.060	1.180	0.260	0.280	0.280
Transport_A	20	34	2.950	-0.090	0.710	0.830	-0.0800	-0.0600	-0.0600
Transport_B	21	35	3.880	-0.140	0.670	0.780	-0.120	-0.100	-0.100
Other	22	36	-0.910	-1.370	-1.690	-1.580	-2.460	-2.450	-2.440

Notes: This table reports the GE effects of a hypothetical RTA between UK and US on all US sectors in our sample. The simulated scenario allows for labor to be mobile across sectors. Column (3) reports effects on total exports. Column (4) reports effects on consumer prices. Columns (5) and (6) report estimates for nominal and real GDP. Finally, columns (7)-(9) report impact on each type of labor. See text for further details.

Appendix: Additional GE Estimates

This Appendix includes additional GE results as referred to in the main text. The following tables are included:

- Table 8: GE Effects of the UK-US RTA on the British Economy, Mobile Labor.
- Table 9: GE Effects of the UK-US RTA on the US Economy, Immobile Labor.
- Table 10: GE Effects of the UK-US RTA on the British Economy, Immobile Labor.
- Table 11: Cross-country GE Effects of the UK-US RTA, Immobile Labor.

Table 8: GE Effects of the UK-US RTA on the British Economy, Mobile Labor

SECTOR LABEL	SECTOR ID	ISIC	%Δ Trade	%Δ CPI	%Δ GDP	%Δ Real GDP	%Δ L_Prim	%Δ L_Sec	%Δ L_Ter
Food	1	15	3.170	-0.350	-0.270	0.420	-3.130	-3.480	-3.540
Tobacco	2	16	3.390	0.0900	1.910	2.620	-1.000	-1.350	-1.420
Textiles	3	17	0.620	-1.180	-0.530	0.160	-3.380	-3.730	-3.800
Apparel	4	18	19.94	0.0500	7.280	8.030	4.210	3.840	3.760
Leather	5	19	15.63	0.0300	6.720	7.460	3.660	3.290	3.220
Wood	6	20	1.390	-1.010	-0.350	0.350	-3.200	-3.550	-3.620
Paper	7	21	-4.680	-1.680	-5.500	-4.840	-8.210	-8.530	-8.600
Printing	8	22	2.770	-0.700	-0.0600	0.640	-2.930	-3.270	-3.340
Petroleum	9	23	-0.900	-0.640	-0.630	0.0600	-3.480	-3.820	-3.890
Chemicals	10	24	12.72	-0.820	4.390	5.120	1.410	1.040	0.980
Rubber	11	25	1.610	-0.790	-0.0900	0.610	-2.950	-3.290	-3.360
Minerals	12	26	12.93	-0.0700	3.340	4.060	0.380	0.0200	-0.0500
Metals_A	13	27	8.370	-0.360	2.850	3.570	-0.100	-0.450	-0.520
Metals|_B	14	28	7.300	-0.160	3.280	4.000	0.320	-0.0300	-0.100
Machinery_A	15	29	19.32	-0.750	5.600	6.330	2.560	2.200	2.130
Machinery_B	16	30	24.59	0.0200	8.610	9.370	5.510	5.130	5.060
Electrical_A	17	31	22.26	-0.350	7.940	8.690	4.850	4.470	4.400
Electrical_B	18	32	13.12	-2.040	3.940	4.660	0.960	0.600	0.530
Medical	19	33	15.68	-3.820	5.020	5.750	2.000	1.640	1.570
Transport_A	20	34	8.660	-0.580	2.850	3.570	-0.100	-0.450	-0.520
Transport_B	21	35	11.07	-0.830	1.940	2.650	-0.980	-1.330	-1.400
Other	22	36	17.14	-0.420	7.460	8.210	4.390	4.010	3.940

Notes: This table reports the GE effects of a hypothetical RTA between UK and US on all UK sectors in our sample. The simulated scenario allows for labor to be mobile across sectors. Column (3) reports effects on total exports. Column (4) reports effects on consumer prices. Columns (5) and (6) report estimates for nominal and real GDP. Finally, columns (7)-(9) report impact on each type of labor. See text for further details.

Table 9: GE Effects of the UK-US RTA on the US Economy, Immobile Labor

SECTOR LABEL	SECTOR ID	ISIC CODE	%Δ Trade	%Δ CPI	%Δ GDP	%Δ Real GDP
Food	1	15	3.650	-0.0100	0.990	1.110
Tobacco	2	16	0.200	-0.0100	0.290	0.410
Textiles	3	17	5.740	0.0200	1.680	1.800
Apparel	4	18	1.160	-0.230	-0.270	-0.150
Leather	5	19	1.360	-0.520	-1.730	-1.610
Wood	6	20	7.620	0.0200	1.620	1.740
Paper	7	21	4.810	0.0200	1.590	1.710
Printing	8	22	1.960	-0.0500	0.720	0.840
Petroleum	9	23	1.610	0.0300	0.750	0.860
Chemicals	10	24	2.370	-0.140	0.520	0.640
Rubber	11	25	4.530	0.000	1.150	1.270
Minerals	12	26	3.680	-0.0300	0.650	0.770
Metals_A	13	27	6.100	-0.0100	0.960	1.080
Metals|_B	14	28	1.240	-0.0600	0.430	0.550
Machinery_A	15	29	4.480	-0.190	0.540	0.660
Machinery_B	16	30	2.820	-0.280	-0.540	-0.430
Electrical_A	17	31	3.020	-0.170	0.450	0.570
Electrical_B	18	32	6.820	-0.0500	1.970	2.090
Medical	19	33	3.100	-0.190	1.020	1.140
Transport_A	20	34	2.950	-0.0900	0.700	0.820
Transport_B	21	35	3.880	-0.140	0.650	0.770
Other	22	36	-0.910	-1.380	-1.640	-1.520

Notes: This table reports the GE effects of a hypothetical RTA between UK and US on all US sectors in our sample. The simulated scenario does not allow for labor to be mobile across sectors. Column (3) reports effects on total exports. Column (4) reports effects on consumer prices. Columns (5) and (6) report estimates for nominal and real GDP. See text for further details.

Table 10: GE Effects of the UK-US RTA on the British Economy, Immobile Labor

SECTOR LABEL	SECTOR ID	ISIC CODE	%Δ Trade	%Δ CPI	%Δ GDP	%Δ Real GDP
Food	1	15	3.170	-0.370	-0.240	0.460
Tobacco	2	16	3.390	0.0800	1.900	2.610
Textiles	3	17	0.620	-1.190	-0.460	0.240
Apparel	4	18	19.94	0.0600	7.110	7.860
Leather	5	19	15.63	0.0500	6.560	7.300
Wood	6	20	1.390	-1.020	-0.380	0.320
Paper	7	21	-4.680	-1.710	-5.350	-4.690
Printing	8	22	2.770	-0.730	-0.0100	0.690
Petroleum	9	23	-0.900	-0.650	-0.660	0.0400
Chemicals	10	24	12.72	-0.820	4.350	5.080
Rubber	11	25	1.610	-0.810	-0.0700	0.630
Minerals	12	26	12.93	-0.0700	3.300	4.030
Metals_A	13	27	8.370	-0.360	2.810	3.530
Metals|_B	14	28	7.300	-0.160	3.230	3.950
Machinery_A	15	29	19.32	-0.740	5.470	6.210
Machinery_B	16	30	24.59	0.0400	8.440	9.200
Electrical_A	17	31	22.26	-0.340	7.740	8.500
Electrical_B	18	32	13.12	-2.040	3.880	4.610
Medical	19	33	15.68	-3.820	4.910	5.650
Transport_A	20	34	8.660	-0.580	2.830	3.550
Transport_B	21	35	11.07	-0.830	1.980	2.690
Other	22	36	17.14	-0.410	7.280	8.030

Notes: This table reports the GE effects of a hypothetical RTA between UK and US on all UK sectors in our sample. The simulated scenario does not allow for labor to be mobile across sectors. Column (3) reports effects on total exports. Column (4) reports effects on consumer prices. Columns (5) and (6) report estimates for nominal and real GDP. See text for further details.

Table 11: Cross-country GE Effects of the UK-US RTA, Immobile Labor

ISO	NAME	%Δ Trade	%Δ CPI	%Δ GDP	%Δ Real GDP
ARG	Argentina	-0.300	-0.0001	-0.104	-0.104
AUS	Australia	-0.191	0.0001	-0.0488	-0.0488
AUT	Austria	-0.373	-0.0008	-0.136	-0.135
BEL	Belgium	-0.366	-0.0004	-0.128	-0.127
BGR	Bulgaria	-0.280	-0.0002	-0.0925	-0.0923
BRA	Brazil	-0.389	-0.00140	-0.138	-0.137
CAN	Canada	-0.407	0.0021	-0.101	-0.103
CHE	Switzerland	-0.443	-0.0009	-0.152	-0.151
CHN	China	-0.231	-0.0011	-0.0863	-0.0852
CZE	Czech Republic	-0.342	-0.0003	-0.119	-0.119
DEU	Germany	-0.380	0.000	-0.121	-0.121
DNK	Denmark	-0.354	0.0001	-0.120	-0.120
DOM	Dominican Republic	-1.125	0.0003	-0.439	-0.439
DZA	Algeria	-0.351	-0.0001	-0.131	-0.131
EGY	Egypt, Arab Rep.	-0.250	-0.000500	-0.0700	-0.0695
ESP	Spain	-0.344	0.0001	-0.124	-0.124
FIN	Finland	-0.453	-0.0004	-0.163	-0.163
FRA	France	-0.386	0.0002	-0.138	-0.138
GBR	United Kingdom	11.89	-0.694	2.845	3.563
GRC	Greece	-0.282	-0.0004	-0.0968	-0.0963
HUN	Hungary	-0.365	-0.0007	-0.123	-0.122
IDN	Indonesia	-0.308	-0.0014	-0.111	-0.109
IND	India	-0.214	-0.0006	-0.0692	-0.0685
IRL	Ireland	-0.874	0.0026	-0.331	-0.333
ITA	Italy	-0.373	-0.0005	-0.126	-0.126
JPN	Japan	-0.318	-0.0014	-0.114	-0.113
KOR	Korea	-0.319	-0.0013	-0.123	-0.122
LTU	Lithuania	-0.393	-0.0003	-0.146	-0.146
MEX	Mexico	-0.607	-0.0002	-0.195	-0.195
MYS	Malaysia	-0.309	-0.0014	-0.111	-0.110
NLD	Netherlands	-0.453	-0.0005	-0.161	-0.161
NOR	Norway	-0.434	0.0002	-0.165	-0.165
OAS	Taiwan	-0.303	-0.00130	-0.109	-0.108
PHL	Philippines	-0.305	-0.0008	-0.108	-0.107
POL	Poland	-0.367	-0.0006	-0.134	-0.133
PRT	Portugal	-0.366	-0.0001	-0.130	-0.130
ROM	Romania	-0.321	-0.0002	-0.112	-0.111
RUS	Russia	-0.280	-0.0005	-0.0917	-0.0912
SVK	Slovakia	-0.369	-0.0005	-0.132	-0.132
SWE	Sweden	-0.419	-0.0001	-0.146	-0.146
THA	Thailand	-0.330	-0.0013	-0.119	-0.118
TUR	Turkey	-0.281	-0.0003	-0.0885	-0.0882
UKR	Ukraine	-0.255	-0.0003	-0.0843	-0.0840
USA	United States	2.983	-0.118	0.773	0.891
VNM	Vietnam	-0.332	-0.0007	-0.129	-0.128

Notes: This table reports the GE effects of a hypothetical RTA between UK and US on all countries in our sample. The simulated scenario does not allow for labor to be mobile across sectors. Column (3) reports effects on total exports. Column (4) reports effects on consumer prices. Columns (5) and (6) report estimates for nominal and real GDP. See text for further details.