TRADE AND FRICTIONAL UNEMPLOYMENT IN THE GLOBAL ECONOMY*

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Abstract

We develop a multi-country, multi-sector trade model with labor market frictions and equilibrium unemployment. Trade opening leads to a reduction in unemployment if it raises real wages and reallocates labor towards sectors with lower-than-average labor market frictions. We estimate sector-specific labor market frictions and trade elasticities using employment data from 25 OECD countries and worldwide trade data. We then quantify the potential unemployment and real wage effects of implementing the Transatlantic Trade and Investment Partnership (TTIP) or the Trans-Pacific Partnership (TPP), and of eliminating trade imbalances worldwide. The unemployment and real wage effects work in conflicting directions for some countries under some trade regimes, such as the US under TTIP. We introduce a welfare criterion that accounts for both effects and splits such ties. Accordingly, US welfare is predicted to decrease under TTIP and increase under TPP.

Keywords: labor market frictions, unemployment, trade

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1 Introduction

It is widely accepted that trade usually raises real incomes. But does it create jobs? The current US administration seems to believe so. In an opinion article published on January 15, 2015, Secretary of State John Kerry wrote:

> 'Estimates are that the TPP [Trans-Pacific Partnership] could provide $77 billion a year in real income and support 650,000 new jobs in the U.S. alone.'[1]

By contrast, Peter A. Petri from the Peterson Institute rejects the very idea that trade has any aggregate impact on employment, echoing Krugman (1993):

> 'Like most trade economists, we don't believe that trade agreements change the labor force in the long run. [...] Rather, trade agreements affect how people are employed, and ideally substitute more productive jobs for less productive ones and thus raise real incomes.'[2]

We argue that there is some truth in both of these seemingly contradictory views and that trade may simultaneously raise incomes and unemployment. We propose a framework to evaluate trade reforms when society (governments or individuals) cares about both incomes and unemployment. Preferential trade agreements or any other trade reform may affect the unemployment rate of a country via two channels. First, if a trade shock results in efficiency gains in a country then this raises both real incomes and – in the presence of labor market frictions – job creation in that country. Second, the reallocation of the workforce itself may raise or diminish the equilibrium unemployment rate if labor market frictions vary across sectors (and we find that they do).

In the first half of the paper, we develop our argument by designing a multi-sector, multi-country general equilibrium trade model with labor market frictions and equilibrium unemployment. Our model emphasizes both aforementioned channels whereby trade shocks such as preferential trade agreements affect the aggregate unemployment rate of a country. The *reallocation* effect of a trade reform leads to an increase in unemployment if it reallocates labor into sectors with higher-than-average labor market frictions. The *expansion* effect is a general equilibrium effect whereby a trade reform, by boosting allocative efficiency, may spur aggregate job creation, which in turn raises real wages and reduces unemployment in all sectors. The multi-sector, multi-country design of our model emphasizes that the reallocation and expansion effects of a preferential (i.e. discriminatory) trade agreement on the real income and unemployment rate of a country depend on the set of countries and sectors included in the agreement it is signing. It also opens the possibility that trade simultaneously raises real incomes and unemployment when both effects work in conflicting directions, as seemingly happened in e.g. Columbia in the late twentieth century (Coşar, Guner, and Tybout, 2016).

[1] See `http://www.project-syndicate.org/commentary/american-alliances-international-cooperation-by-john-f--kerry-2015-01#4bxmfbYemSPg1fzI.99`, accessed on October 30, 2015.

[2] See `https://www.washingtonpost.com/news/fact-checker/wp/2015/01/30/the-obama-administrations-illusionary-job-gains-from-the-trans-pacific-partnership/` accessed on October 30, 2015.

In the second half of the paper, we structurally estimate the parameters of the model using world trade data for over 130 countries and sectoral employment and production data for 25 OECD countries (henceforth OECD-25) over 2001-2008; a key contribution of the paper is to estimate sector-specific labor market frictions from the OECD-25 production data in a theory-consistent way.[3] Equipped with this, we run a first counterfactual exercise, namely, we estimate the real wage and unemployment effects for all countries in our sample of eliminating trade barriers including all (already mostly low) tariffs between the US and the EU – as is the ostensible goal of the Transatlantic Trade and Investment Partnership (henceforth TTIP). We find that such elimination of trade barriers has minor and heterogeneous unemployment and welfare effects on EU countries. In the US, total unemployment is predicted to rise by 1.1% but real wages would also rise, by 0.3% on average; the net welfare effect is thus ambiguous *a priori*. We introduce a welfare criterion that accounts for both real wage and unemployment effects in order to resolve such ambiguity. According to our criterion, TTIP is predicted to have a (minor) negative effect on US welfare. As could be expected, the welfare, real wage, and employment effects of TTIP on non-participating OECD countries are usually negative and small. We then perform a similar exercise for the Trans-Pacific Partnership free trade agreement, or TPP, as our second counterfactual scenario. Again, we find that welfare increases for the member countries of our sample and decreases – slightly – for the non-participating ones. Our final counterfactual scenario involves the removal of trade imbalances. Here, real wage, unemployment, and welfare effects are much larger in magnitude and also more heterogeneous than under the previous scenarios. The general pattern that emerges is that surplus countries usually benefit from the removal of trade imbalances while deficit countries are made worse off, as the recent Greek example illustrates vividly.

Designing a multi-country, multi-sector general equilibrium model of trade and equilibrium unemployment is important for several reasons. First, trade economists tend to focus on the real wage effects of trade, sometimes dismissing its unemployment effects as of second-order importance, even as policymakers and the public at large tend to voice concerns and support for trade agreements in terms of jobs gained or lost.[4] By explicitly including search-and-matching labor market frictions in an otherwise standard trade model, we take these concerns seriously. Specifically, we introduce sector-specific Diamond-Mortensen-Pissarides search-and-matching frictions, as modeled in the static model of Helpman and Itskhoki (2010), into a multi-country Ricardian trade model à-la Eaton and Kortum (2002) and Costinot, Donaldson, and Komunjer (2012). As a result, equilibrium trade patterns have non-trivial effects on equilibrium unemployment.

Second, we show that real wage and frictional unemployment effects are closely – but only imperfectly – correlated. Both the distinctions and the similarities between the two criteria are important.

[3]More precisely, we estimate one parameter per sector (μ_k), which is a combination of the sector-specific vacancy cost (which encompasses training costs in our static model) and of the sector-specific matching total factor productivity (TFP). We refer to this parameter as the *matching efficiency* of the sector for short.

[4]See also e.g. Lü, Scheve, and Slaughter (2012) for evidence that labor market outcomes shape attitudes towards trade in China and the US.

Any reform that raises aggregate demand boosts job creation, which raises wages and reduces unemployment in all sectors (the *expansion effect*); thus, focusing on aggregate unemployment, as policymakers tend to do, or on real incomes, as economists usually do, looks like looking at the same issue from two different angles. But this view misses the other half of the story whereby trade reforms reallocate resources across sectors. This *reallocation effect* has an impact on a country's unemployment rate if sectors exhibit heterogeneous labor market frictions and, as a consequence, heterogeneous unemployment rates, as manufacturing sectors do in the US (see Figure 1). These differences in US sectoral unemployment rates are also highly persistent: observe that these rates increase and decrease in parallel fashion along the business cycle. The sources of such frictions include sector-specific hiring or training costs. The main empirical contribution of this paper is to design an estimation strategy to measure these sector-specific labor market frictions in a theory-consistent way using OECD data for 35 non-traded and traded sectors (including 21 manufacturing sectors). We obtain substantial cross-sectoral variation. We then perform several tests to evaluate the empirical robustness of these estimates across countries and over time. As a first external validity test, we check that such estimated sector-specific frictions correlate well with observed sectoral unemployment rates for which we have data (US manufactures), as illustrated in Figure 1. As a second external validity test, we find that these estimates are a good predictor of aggregate unemployment in 2011, an out-of-sample year. Finally, in line with theory, we demonstrate that estimates of these sector-specific frictions are robust across countries and stable over time: they thus have concrete empirical relevance and real predictive power.[5]

Third, most existing studies on the labor market outcomes of the interaction of trade reforms with labor market frictions estimate the transition effects (e.g. Artuç, Chaudhuri, and McLaren 2010, Dix-Carneiro 2014, Fajgelbaum 2013). Reallocating labor across sectors and firms takes time and several workers become temporarily unemployed, some for a substantial amount of time.[6] We complement such studies by looking at the effects of trade on frictional unemployment.

Finally, our framework is quite flexible and much of the data needed to estimate the model are readily available. These make it easily amenable to policy evaluations. We illustrate by estimating the welfare, real wage, and frictional unemployment effects on our OECD-25 sample of countries of removing trade barriers between EU countries and the US (as in the TTIP preferential trade agreement) or among twelve Asia Pacific countries (as in the TPP agreement), and of removing trade imbalances in the spirit of Eaton, Kortum, and Neiman (2013). Other applications are possible (e.g. 'Brexit', 'Grexit').

The normative contribution of the paper is to provide a rationale for the public's interest in the employment effects of trade. In our (Ricardian) model, all workers are *ex-ante* identical but some end up in involuntary unemployment ex-post. In addition, employed workers end up working in different

[5]A complementary paper (Carrère, Fugazza, Olarreaga, and Robert-Nicoud 2014) finds that countries that have a comparative advantage in labor market friction-intensive sectors experience an increase in unemployment following trade liberalization episodes. This evidence is consistent with the *reallocation effect*. In the current paper, we estimate these sector-specific frictions but we do not test the consequences of the reallocation effect.

[6]We account for the transition effects in our empirical framework using country-specific time dummies.

sectors and earning different wages in equilibrium (though *ex ante* expected wages are equalised across sectors). If society is averse to inequality then we show that maximising a social welfare function as in Atkinson (1970) is conceptually similar to optimizing over a geometric combination of the average real wage and the unemployment rate.[7] This is an important and intuitive result: our model features *ex post* unequal treatment of equals, something valued negatively by a society averse to inequality. Also, in this setting, trade can lead to Stolper-Samuelson-like distributional effects between employed and unemployed workers. Both of these effects may explain the expansion of the welfare state in inequality-averse open economies as emphasized by Rodrik (1998) and Epifani and Gancia (2007). Finally, our paper contributes to the recent debate on the gains from trade sparked by Arkolakis, Costinot, and Rodríguez-Clare (2012).[8] We generalize their formula to our multi-sector environment with labor market frictions. Our model also emphasizes that average real wages are only one (arguably major) component of welfare in the presence of labor market frictions and societal aversion to inequality. In this way, our paper is also related to the literature on trade-induced wage inequality.[9]

We further contribute to the existing literature on four accounts. First, we complement papers that study labor market outcomes of various trade regimes (see Helpman, Itskhoki, and Redding, 2013, for a review).[10] Our contribution to this literature is to build on these by developing a multi-sector, multi-country trade model featuring Diamond-Mortensen-Pissarides labor market frictions. Several features of such a framework are noteworthy: (*i*) it generalizes the central theoretical predictions of two-country and/or two-sector trade models to a more realistic environment, which (*ii*) allows us to study the consequences of discriminatory trade liberalisation; (*iii*) its key parameters can be structurally estimated using trade and unemployment data, based on which (*iv*) we can use it to run counterfactual experiments. Felbermayr, Prat, and Schmerer (2011), Helpman, Itskhoki, and Redding (2012), and Coşar, Guner, and Tybout (2016) extend this literature to 'new trade models' with monopolistic competition and heterogeneous firms. As these works make clear, this important extension comes at

[7] According to this criterion, the planner puts all weight on real wages in the limiting case of no inequality aversion (Bentham) and on unemployment in the polar case of extreme inequality aversion (Rawls). Appendix C also reports results for the alternative criterion put forth by Sen (1976).

[8] See in particular Atkeson and Burstein (2010), Head, Mayer, and Thoenig (2014), Melitz and Redding (2015), Edmond, Midrigan, and Xu (2015), and Ossa (2015).

[9] See e.g. Antràs, de Gortari, and Itskhoki (2016), Burstein and Vogel (2015), Faber and Fally (2015), Helpman, Itskhoki, and Redding (2010), Helpman, Itskhoki, Muendler, and Redding (2015), Krishna, Pool, and Senses (2012), and Verhoogen (2008); Goldberg and Pavcnik (2007) provide a review of the empirical literature on developing countries.

[10] Brecher (1974) and Davis (1998) set up two-country Heckscher-Ohlin models in which the patterns of trade interact with minimum wages. Davidson, Martin, and Matusz (1988, 1999), Costinot (2009), Helpman and Itskhoki (2010), and Carrère, Fugazza, Olarreaga, and Robert-Nicoud (2014) embed Diamond-Mortensen-Pissarides labor market frictions into two-country or small-open-economy homogeneous-firm trade models. Heid and Larch (2016) embed labour market frictions into a flexible many-country trade model in which goods are differentiated by country of origin only as in Armington (1969). Another important strand of this literature considers the impact of trade on unemployment caused by 'efficient' or 'fair wages', as in Davis and Harrigan (2011), Egger and Kreickemeier (2012), and Kreickemeier and Nelson (2006).

the cost of analytical tractability as these models do not easily lend themselves to generalisations to settings featuring large and asymmetric open economies with income effects (as our paper does).

Second, our paper recognizes that labor-market frictions can be a source of comparative advantage like Cuñat and Melitz (2012), Davidson, Martin, and Matusz (1988), and Helpman and Itskhoki (2010). In our framework, trade patterns depend on sector-specific labor market frictions and sector-specific total factor productivity in a perfectly symmetric fashion.

Third, our paper contributes to the lively policy and academic literature on the economic effects of TTIP, TPP, and trade rebalancing.[11] Most of these papers, including Heid and Larch (2016), display the expansion effect but none features our reallocation effect.[12] We argue that this reallocation effect is significant and sizeable, in line with available evidence from developed countries that employment adjusts across sectors in response to trade shocks (see e.g. Revenga, 1992, for the US and Trefler, 2004, for Canada).[13] In our OECD-25 sample, we find that this composition effect is a dominating component in explaining cross-sectional variation in employment rate across countries.

Finally, our application of a welfare criterion to a trade context is quite novel; we are aware of only two ongoing papers using such criteria. Antràs, de Gortari, and Itskhoki (2016) and Galle, Rodríguez-Clare, and Yi (2015) apply the Atkinson (1970) social welfare function to study the distributional consequences of trade reforms among heterogeneous agents. We use this criterion (as well as Sen's 1976) in a context in which labor-market search frictions generate involuntary unemployment and thus ex post unequal treatment of homogeneous workers. To the extent that trade gains are not redistributed through unemployment benefits, there are winners and losers in terms of employment or earnings, or both. This affects welfare negatively in inequality-averse societies and this welfare loss may erode part or all of the real wage gains from trade.

The rest of the paper is structured as follows. Sections 2, 3, and 4 introduce technology, preferences, and labor market frictions, respectively. Proposition 1 summarizes the properties of the autarky equilibrium unemployment rate and average real wage. Section 5 allows for international trade and derives sufficient conditions, summarized in Proposition 2, under which gains from trade are associated with less unemployment. Proposition 3 establishes conditions for this result to extend to inequality-averse

[11] Papers that estimate economic effects of the TTIP include the Bertelsmann (2013) report as well as Aichele, Felbermayr, and Heiland (2014), Egger, Francois, Manchin, and Nelson (2015), Felbermayr, Heid, Larch, and Yalcin (2015), Fontagné, Gourdon, and Jean (2013), and Francois, Manchin, Norberg, Pindyuk, and Tomberger (2013). Petri, Plummer and Zhai (2012) analyse the economic effects of TPP. Eaton, Kortum, and Neiman (2013) look at the unemployment consequences of current account imbalances.

[12] Like us, Heid and Larch develop a microeconomically founded gravity trade model with labor market frictions. Though their microeconomics foundations and ours are very different (Armington versus Ricardo), several qualitative and quantitative predictions are common to both settings. The key difference between their work and ours is that our model features an arbitrary number of sectors in all countries, which generates new theoretical predictions that we test in our empirical section.

[13] Such reallocation effect seems to be absent in developing countries. See e.g. Levinsohn (1999), Menezes-Filho and Muendler (2011), and McCaig and Pavcnik (2012).

open economies. Finally, Section 6 estimates the parameters of the model, Section 7 presents the results of a series of counterfactual exercises, and Section 8 concludes.

2 Technology and production

Consider a world comprising I countries, labelled with subscripts i and j. There are K final good sectors in the world economy that use a single factor of production, labor L, for production. Each sector k produces a differentiated good consisting of potentially infinitely many (countable) different varieties $x \in \mathbb{X}_{ik} \subseteq \mathbb{N}$ as in Costinot, Donaldson, and Komunjer (2012). Technology exhibits constant returns to scale and is variety- and country-specific. Specifically, let the output level be defined as

$$\mathbb{Q}_{ik}(x) = \varphi_{ik}(x) H_{ik}(x), \tag{1}$$

where $H_{ik}(x)$ is the number of production workers and $\varphi_{ik}(x)$ is productivity level of the representative firm producing variety x in sector k in country i. This technology parameter has a deterministic component, φ_{ik}, which is country- and sector- specific, and a stochastic component, which is the outcome of a random process such that productivity differs across varieties. Specifically, we assume that $\varphi_{ik}(x)$ is drawn independently for all (i, k, x) from a Fréchet distribution with shape parameter θ such that

$$F_{ik}(\varphi) = \exp\left[-\left(\frac{\varphi}{\varphi_{ik}}\right)^{-\theta}\right],$$

where the scale parameter $\varphi_{ik} > 0$ governs absolute productivity levels and the shape parameter $\theta > 1$ is negatively related to the scope for comparative advantage across varieties: the lower θ, the higher the dispersion of the φ_{ik}'s.[14]

3 Demand and preferences

We assume that the representative consumer in country i is risk neutral, spends a constant share α_{ik} of her income on the composite good produced by sector k, and holds CES preferences across the varieties within each sector:

$$\mathbb{U}_i = \prod_{k=1}^{K} \mathbb{Q}_{ik}^{\alpha_{ik}}, \quad \text{where} \quad \mathbb{Q}_{ik} = \left[\sum_{x \in \mathbb{X}_{ik}} \mathbb{Q}_{ik}(x)^{1-1/\sigma}\right]^{\frac{1}{1-1/\sigma}} \tag{2}$$

and $\sum_k \alpha_{ik} = 1$ for all i. The various $\mathbb{Q}$'s stand for quantities consumed, $\mathbb{X}_{ik}$ is the set of sector k varieties that are available for consumption in country i, and $\sigma < 1 + \theta$ is the common elasticity of substitution between any pair of varieties.

[14] To see this, let $\theta > 2$ (so that the first and second moments of F both exist) and note that $\mathbb{E}(\varphi^2)/\mathbb{E}(\varphi)^2$ is equal to $\Gamma(1 - 2/\theta)/\Gamma(1 - 1/\theta)$, which is decreasing in θ by $\Gamma'(.) > 0$, where $\Gamma(\cdot)$ is the gamma function.

It follows from (2) that expenditure in any country i on variety x of good k is given by

$$E_{ik}(x) = \left[\frac{p_{ik}(x)}{p_{ik}}\right]^{1-\sigma} \alpha_{ik} E_i, \tag{3}$$

where E_i is the aggregate expenditure in country i, p denotes prices, and

$$p_{ik} \equiv \left[\sum_{x \in \mathbb{X}_{ik}} p_{ik}(x)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{4}$$

is the price index for good k in country i (i.e. it is the dual of $\mathbb{Q}_{ik}$). It follows from (2) that the unit price of the bundle $\mathbb{U}_i$ is equal to the geometric weighted average of the sectoral prices:

$$\mathbb{P}_i = \prod_{k=1}^{K} p_{ik}^{\alpha_{ik}}. \tag{5}$$

4 Labor market frictions, wage bargaining, and equilibrium (un)employment

Each country i is endowed with an inelastic labor force $\bar{L}_i$. An infinitely elastic supply of potential firms may enter the labor market by opening vacancies. There are search-and-matching frictions in the labor market. This generates hiring costs and matching rents over which the firm and the employee bargain, as we explain in detail below.

In our model labor market frictions are *sector*-specific. That is, each sector is a segmented labor 'submarket' (Barnichon and Figura, 2015). An alternative, equally plausible hypothesis, is that labor market frictions are *occupation*-specific. In this case, at equilibrium, a sector-specific friction is a weighted average of the frictions pertaining to the occupations employed by the sector, as we show in Appendix A.[15] For the sake of simplicity (and without loss of generality), we thus develop the more parsimonious model (without explicit occupations) in the main text.

4.1 Matching frictions

Firms open vacancies and workers search for jobs. Let V_{ik} denote the endogenous number of open vacancies and let L_{ik} denote the endogenous mass of workers who seek employment in sector k, country i. We denote the subset of those workers who are actually hired in sector k by H_{ik}.

[15] In Appendix A, we build a model with an additional layer of occupations. Labor market frictions operate at this layer. Each sector combines various occupations with its specific Cobb-Douglas technology. The properties of the equilibrium at the sector level of this alternative model are identical to those of the more parsimonious model that we develop in the main text. By the same token, we could add input-output linkages among sectors.

We assume a Cobb-Douglas matching technology, so that the number of successful matches (and thus of hired workers) in each sector equals

$$H_{ik} = \tilde{\mu}_{ik} V_{ik}^{1-\lambda} L_{ik}^{\lambda}, \tag{6}$$

where the total factor productivity (TFP) of the matching process, $\tilde{\mu}_{ik}$, varies across countries and sectors and where $\lambda \in (0,1)$ is the labor share in the matching process. There is sectoral equilibrium unemployment whenever $H_{ik} < L_{ik}$. We define the *employment rate* in sector k as

$$\ell_{ik} \equiv \frac{H_{ik}}{L_{ik}}. \tag{7}$$

Helpman and Itskhoki (2010) refer to ℓ_{ik} as the tightness of the labor market in sector k, country i. It is also the equilibrium probability of finding a job in this sector conditional on searching in it.

Let the parameter ν_{ik} denote the unit vacancy cost. In our setting, this vacancy cost includes sector-specific training costs and such costs vary greatly across sectors. For simplicity, we assume that ν is paid in units of the domestic consumption bundle $\mathbb{U}$ only; Appendix B works out a more general case in which ν is paid in terms of a Cobb-Douglas combination of labor and $\mathbb{U}$ and establishes that all qualitative results and most quantitative results go through unaltered.[16] For each worker actually hired, V_{ik}/H_{ik} vacancies need be open. Thus the per worker hiring cost is equal to $\mathbb{P}_i \nu_{ik} V_{ik}/H_{ik}$. Using (6) and (7), this cost is equal to

$$c_{ik} \equiv \mathbb{P}_i \left(\frac{\ell_{ik}^{\lambda}}{\mu_{ik}} \right)^{\frac{1}{1-\lambda}}, \tag{8}$$

where

$$\mu_{ik} \equiv \frac{\tilde{\mu}_{ik}}{\nu_{ik}^{1-\lambda}} \tag{9}$$

is the *sector-specific matching total-factor productivity* (TFP) *adjusted for vacancy costs*, henceforth *matching efficiency* for short; in other words, μ is the *inverse of all labor market frictions*. Thus, the sector-specific cost of hiring a worker in (8) depends on the tightness of, and on the frictions in, the labor submarket.

Upon forming a match, the firm and the worker bargain over the wage. We turn to this next.

4.2 Wage bargaining

Aggregate revenue of firms in the triple (i,k,x) is equal to consumer expenditure in equilibrium and is defined as $E_{ik}(x) \equiv p_{ik}(x)\mathbb{Q}_{ik}(x)$. Using (1), we rewrite the expression for revenue as $E_{ik}(x) =$

[16] In Appendix B the per worker hiring cost is equal to $\mathbb{P}_i^{\beta} w_{ik}^{1-\beta} \nu_{ik} V_{ik}/H_{ik}$, some $\beta \in [0,1]$. We set $\beta = 1$ in the main text; we show in Appendix B that all qualitative results and most quantitative results go through unaltered for any $\beta \in (0,1]$. The polar case $\beta = 0$ implies that search costs are proportional to wages so that trade has no impact on the relative cost of labor; we emphasize the consequences of this assumption in the relevant subsections below.

$p_{ik}(x)\varphi_{ik}(x)H_{ik}(x)$, which implies that revenue is linear in labor.[17] Let

$$r_{ik}(x) \equiv \frac{E_{ik}(x)}{H_{ik}(x)} = p_{ik}(x)\varphi_{ik}(x) \tag{10}$$

define the revenue per worker of the representative firm. Once matched, the firm and the worker bargain over the firm-specific wage, $w_i^k(x)$, in order to split the joint revenue $r_{ik}(x)$ in a cooperative fashion. They take all other prices as given. Disagreeing and breaking the match has an opportunity cost because it implies searching for another partner, which is costly because of matching frictions. Thus, upon matching, $r_{ik}(x)$ is a *rent* over which the worker and the firm bargain. For simplicity, we assume equal bargaining weights so that the firm and the worker each get $r_{ik}(x)/2$ (Helpman and Itskhoki, 2010). Note that the size of a firm is irrelevant by virtue of constant returns to labor: the firm bargains with each worker independently and the outcome of its bargaining with one worker has no impact on its bargaining situation with any other worker. It then follows that the wage in the triple (i, k, x) is equal to

$$w_{ik}(x) = \frac{1}{2}\frac{E_{ik}(x)}{H_{ik}(x)}.$$

From the point of view of the firm, replacing a worker entails the sector- and country-specific search cost c_{ik} defined in (8), which is exogenous to the individual firm x. Any firm finds it optimal to open vacancies until the equilibrium individual wage, $w_{ik}(x)$, is equal to the cost of replacing a worker, c_{ik}. This implies

$$w_{ik}(x) = w_{ik} = c_{ik} \tag{11}$$

and

$$p_{ik}(x) = c_{ik}(x) = 2\frac{c_{ik}}{\varphi_{ik}(x)},$$

where $c_{ik}(x)$ is the unit cost of production of firm x and $p_{ik}(x) = c_{ik}(x)$ holds by perfect competition. Two properties of (11) and of the pricing expression above are noteworthy. Wages are common across all varieties within a sector but production costs may vary. The latter result holds because heterogeneous costs reflect heterogeneous productivity levels across varieties within each sector. The intuition for the former result is as follows: firms increase employment until the bargaining wage outcome is equal to the cost of replacing a worker. Since c_{ik} is common among all firms in sector k, they all pay the same wage w_{ik} regardless of the productivity $\varphi_{ik}(x)$ with which they actually produce.

4.3 Equilibrium unemployment and utility

All workers actively look for employment, such that the full-participation condition reads as

$$\bar{L}_i = \sum_{k=1}^{K} L_{ik}.$$

[17] We use the notation E for both revenue and expenditure in order to reduce notation proliferation. The two are equal in equilibrium anyway.

Henceforth we assume that workers can freely choose the sector in which they search for a job and that this choice is irreversible.[18] Individuals are assumed to be risk neutral by (2). Together these imply that the expected wage, defined as the sector-specific product of the wage w_{ik} and of the probability of being employed ℓ_{ik}, must be the same across sectors in equilibrium; we denote this common expected wage by w_i.[19] Thus, for all $k \in \{1, ..., K\}$, the no-arbitrage condition

$$w_i = \ell_{ik} w_{ik} \tag{12}$$

holds. Combining this expression with (8) and (11), the expected wage in country i is equal to $w_i = \mathbb{P}_i (\ell_{ik}/\mu_{ik})^{1/(1-\lambda)}$, for any k. Dividing both sides of this expression by $\mathbb{P}_i$ yields

$$\forall k : \qquad \left(\frac{\ell_{ik}}{\mu_{ik}}\right)^{\frac{1}{1-\lambda}} = \frac{w_i}{\mathbb{P}_i} \equiv \omega_i, \tag{13}$$

where ω_i denotes the average (or expected) real wage or indirect utility of workers; since firms make zero profit, this is also the real per capita income. In equilibrium, sectoral employment rates reflect sectoral labor matching efficiency, i.e. $\ell_{ik} \propto \mu_{ik}$, where the factor of proportionality, $\omega_i^{1-\lambda}$, is the same for all sectors. Note also a higher level of per capita real income ω_i is associated with higher levels of employment in all sectors, ceteris paribus. This result is in line with common wisdom among policymakers: if a reform is good for employment then it must be real-wage augmenting. This intuition is incomplete in general (see Section 5) but exact in autarky. We turn to this special case next.

Autarky. Here we show that the unemployment rate u_i and average real wage ω_i are negatively related in the autarky equilibrium. We proceed in steps. First, the fraction of workers looking for a job in sector k is equal to the fraction of income spent on good k, i.e. $L_{ik}/\bar{L}_i = \alpha_{ik}$ all k and all i, by virtue of Cobb-Douglas preferences, constant returns to scale, and perfect competition in all sectors.[20] Second, let $|\mathbb{X}_{ik}| = N$, all i and k, some $N \in \mathbb{N}$, so that the exact price index p_{ik} in (4) obeys

[18] Another way to formalize this is the following. All workers have one unit of learning time and one unit of working time. They use the former to acquire the skills specific to the sector of their choosing. This choice is sunk.

[19] A natural extension of the model, which we pursue in Appendix D, is to assume instead that the representative consumer displays constant relative risk aversion. This generalization brings one minor conceptual change and one new insight: first, w_i and ω_i (defined in (13) below) are the certainty-equivalent nominal and real wages, respectively. Second, individual risk aversion and societal aversion to inequality enter our Atkinson welfare criterion in subsection 5.4 below in an isomorphic way. Though the qualitative and quantitative results are somewhat affected by this generalization, the main text pursues by assuming risk neutrality for simplicity. Appendix D provides details.

[20] From (2), expenditure on good k is equal to $E_{ik} = \alpha_{ik} E_i$. Aggregate national income and consumption, E_i, is a sum of all wages and hiring costs, and is given by

$$E_i = \sum_{k=1}^{K} w_{ik} H_{ik} + \sum_{k=1}^{K} c_{ik} H_{ik} = 2 w_i \bar{L}_i.$$

The value of production in sector k is equal to $(c_{ik} + w_{ik}) H_{ik} = 2 w_{ik} H_{ik}$. Using (7) and the no-arbitrage condition (12) yields $w_{ik} H_{ik} = w_i L_{ik}$. Together, these equilibrium relationships imply the result in the text.

$\gamma^{-1}p_{ik} \xrightarrow{p} w_{ik}/\varphi_{ik}$, where $\gamma > 0$ is defined below.[21] Using the no-arbitrage condition (12) to substitute for w_{ik} in this expression yields

$$p_{ik} = \gamma \frac{w_i}{\varphi_{ik}\ell_{ik}}, \quad \text{where} \quad \gamma \equiv 2\left[\Gamma\left(1 - \frac{\sigma - 1}{\theta}\right) N\right]^{\frac{1}{1-\sigma}} \tag{14}$$

and $\Gamma(\cdot)$ is the gamma function. Third, plugging this expression into the exact price index in (5) yields $\mathbb{P}_i = \gamma w_i \prod_k (\varphi_{ik}\ell_{ik})^{-\alpha_{ik}}$. Using (13) to substitute for ℓ_{ik} and rearranging yields

$$\omega_i^0 = \left[\frac{1}{\gamma}\prod_{k=1}^{K}(\varphi_{ik}\mu_{ik})^{\alpha_{ik}}\right]^{\frac{1}{\lambda}}, \tag{15}$$

where the superscript '0' pertains to autarky equilibrium values. That is to say, the average real wage of a country in autarky is proportional to its aggregate TFP, where the appropriate measure of TFP in our framework includes both the efficiency of the labor matching functions and the TFP of the production functions. Another modification of the usual neoclassical framework is the power $1/\lambda$ at which productivity is being raised. This is because labor accounts for only a fraction of the matching function.

We finally turn to the equilibrium unemployment rate in autarky. Let u_i and ℓ_i denote the countrywide unemployment and employment rates, respectively, with $u_i + \ell_i \equiv 1$. We define country i's unemployment rate as the fraction of the working population that has not found a job in equilibrium:

$$u_i \equiv 1 - \frac{1}{\bar{L}_i}\sum_{k=1}^{K} H_{ik} = 1 - \sum_{k=1}^{K}\frac{L_{ik}}{\bar{L}_i}\ell_{ik}, \tag{16}$$

where the second equality follows from (7), meaning that u_i is a weighted average of all sectoral unemployment rates. Using the autarky equilibrium condition $L_{ik}/\bar{L}_i = \alpha_{ik}$ and (13) to substitute for $L_{ik}/\bar{L}_i$ and ℓ_{ik} in (16) yields

$$u_i^0 = 1 - \left(\omega_i^0\right)^{1-\lambda}\bar{\mu}_i^0, \quad \text{where} \quad \bar{\mu}^0 \equiv \sum_{k=1}^{K}\alpha_{ik}\mu_{ik} \tag{17}$$

is the autarky equilibrium average level of matching efficiency. The equilibrium unemployment rate is decreasing in both the average matching efficiency and in the real wage. We can then use (15) and (17) to establish the following result:

[21] Costinot, Donaldson and Komunjer (2012) assume $\mathbb{X}_{ik} = \mathbb{N}$ so that $N = +\infty$. Here, we assume instead that N is finite (so that p_{ik}, $\mathbb{P}_i$, and ω_i^0 are well defined) and large enough for the quality of the approximation to be reasonably good. This assumption is needed neither in Costinot, Donaldson and Komunjer (because they care only about comparative advantage and thus relative prices) nor in the rest of our paper (because we compare different equilibriums); the N's cancel out in both cases.

Proposition 1 (Equilibrium real wage and aggregate unemployment in autarky). *At the autarky equilibrium: (**i**) nationwide average real wage is increasing in the production* TFP *and labor matching efficiency of any sector; (**ii**) the nationwide unemployment rate is decreasing in the production* TFP *and labor matching efficiency of any sector.*

Proof. (**i**) ω_i^0 is increasing in φ_{ik} and μ_{ik}, all k, by inspection of (15). (**ii**) The TFP terms influence u_i^0 both directly and indirectly. The direct effect of μ_{ik} on u_i^0 is negative by inspection of (17). The indirect effects of φ_{ik} and μ_{ik} on u_i^0 work via ω_i^0 and they are negative by inspection of (17) and by step (**i**). ■.

5 Trade equilibrium

Proposition 1 implies that the real wage and unemployment are perfectly and negatively correlated, given the preference and matching technology vectors α_i and μ_i. Many a policymaker would find this tautological. However, this logic is incomplete when countries trade. The reason for this is as fundamental as it is simple: our measure of utility is real *consumption.* Unemployment is foregone *production.* The whole point of international trade is to disentangle what a country consumes from what it produces. Trade thus relaxes the tight relationship between our measure of real wage and the unemployment rate.

5.1 Trade frictions and trade flows

All markets are perfectly competitive and there are heterogeneous costs to trade. These costs take the standard iceberg form (Samuelson 1952), such that only a fraction $1/\tau_{ijk}$ of the goods shipped from country i to country j reach their destination. We impose (i) $\tau_{ijk} > \tau_{iik}$ for all (i, j, k) with $i \neq j$, and (ii) $\tau_{ilk} \leq \tau_{ijk}\tau_{jlk}$. Here, (i) states that trade across international borders is costlier than trade within countries; and (ii) is a technical condition that rules out cross-country arbitrage.

Under these assumptions, the all-inclusive cost of delivering variety x in industry k produced in country i and consumed in country j is equal to

$$c_{ijk}(x) = 2\tau_{ijk}\frac{c_{ik}}{\varphi_{ik}(x)}.$$

Countries consume goods from the lowest cost source by virtue of perfect competition. As a result, the equilibrium price of a variety x of good k in country j is such that

$$p_{jk}(x) = \min_i \quad c_{ijk}(x). \tag{18}$$

Let $c_i \equiv w_i^\lambda \mathbb{P}_i^{1-\lambda}$ denote the 'input cost' in country i. Let also

$$t_{ijk} \equiv \frac{\tau_{ijk}}{\varphi_{ik}\mu_{ik}} c_i \tag{19}$$

define the delivery cost of all varieties of sector k that are actually shipped from i to j, and

$$T_{jk} \equiv \left(\sum_{i'=1} t_{i'jk}^{-\theta} \right)^{-\frac{1}{\theta}} \tag{20}$$

be a destination-sector specific term often referred to as the *remoteness* of country j in sector k (Head and Mayer, 2013). Denote finally the value of total exports from country i to country j in sector k by $E_{ijk} \equiv \sum_{x \in \mathbb{X}_{ijk}} E_{ijk}(x)$, where $\mathbb{X}_{ijk} \equiv \{x \in \mathbb{X} \mid c_{ijk}(x) = \min_{i'} c_{i'jk}(x)\}$ is the set of varieties exported by country i to country j in industry k. It then follows from (11), (12), and (18) that bilateral trade flows (in value) at the industry level obey the following gravity equation:

$$E_{ijk} = \pi_{ijk} \alpha_{jk} E_j, \quad \text{where} \quad \pi_{ijk} \equiv \left(\frac{t_{ijk}}{T_{jk}} \right)^{-\theta} \tag{21}$$

is country i's market share in country j's market k.

Inspection of (19) and (21) reveals that country i's volume of exports of good k to country j is increasing in the destination market size, $\alpha_{jk} E_j$. Also, country i's market share is decreasing in its delivery cost to destination j relative to the delivery of all alternative partners. This delivery cost is increasing in trade and transportation costs τ_{ijk} and in the input cost c_i, and it is decreasing in the production TFP's and labor matching efficiencies, φ_{ik} and μ_{ik}, respectively. The novelty with respect to the Ricardian models of Eaton and Kortum (2002) and Costinot, Donaldson and Komunjer (2012) is twofold. First, the overall TFP of a sector is the product of production TFP φ_k and labour matching TFP net of training costs μ_k; see (19). Consequently, they cannot be identified separately using trade flow data as per (21). Second, wages do not enter (19) linearly by $\lambda < 1$ because the matching technology exhibits decreasing returns to labor. This gives rise to the expansion effect as any increase in sales translates into a less-that-proportional increase in wages, the remainder of the effect being partially absorbed by the tightening of labour markets.

In the above, t_{ijk} contains c_i, which is endogenous. The model being block recursive, we can establish that equilibrium vector of c_i's exists and is unique following the method of proof in Alvarez and Lucas (2007).

5.2 Trade and equilibrium (un)employment

Here we encapsulate the model of frictional unemployment of Section 4 into our trade model. It is easier to work with the employment rate ℓ_i than with the unemployment rate u_i (recall that $\ell_i + u_i = 1$ by definition), so we solve for the trade equilibrium employment rate.

Let us define the production share of sector k in country i as

$$s_{ik} \equiv \frac{L_{ik}}{L_i} = \frac{E_{ik}}{E_i},$$

where the second equality follows from $E_{ik} = 2w_{ik}H_{ik} = 2w_i L_{ik}$. Note that the L_{ik}'s are not observable but that we can infer the E_{ik}'s using domestic production data. Using these, we may rewrite (16) as

$$\ell_i \equiv 1 - u_i = \omega_i^{1-\lambda}\bar{\mu}_i, \quad \text{where} \quad \bar{\mu}_i \equiv \sum_{k=1}^{K} s_{ik}\mu_{ik} \tag{22}$$

is the weighted average matching efficiency in country i evaluated at the trade equilibrium. Two features of (22) are noteworthy. First, the equilibrium employment rate depends on both the overall per capita level of GDP and on the sectoral composition of the economy. Second, the elasticity of employment with respect to (real) per capita GDP is strictly positive and equal to $1 - \lambda$: the presence of labor market frictions generates an endogenous employment supply in equilibrium, as does the leisure-consumption choice in Arkolakis and Esposito's (2015) trade model with full employment.[22]

5.3 Gains from trade and employment

We use (22) to compare the actual equilibrium with a counterfactual such as some free trade agreement or balanced trade (as Section 7 illustrates). Variables pertaining to the current equilibrium are unsuperscripted; we use primes to denote the counterfactual equilibrium. Consider first the ratio of per capita GDP's in two configurations. Using (5), (14), and (21), we obtain the following generalized ACR formula (after Arkolakis, Costinot, and Rodríguez-Clare, 2012):

$$\frac{\omega_i'}{\omega_i} = \left(\frac{\bar{\pi}_{ii}'}{\bar{\pi}_{ii}}\right)^{-\frac{1}{\lambda\theta}}, \quad \text{where} \quad \bar{\pi}_{ii} \equiv \prod_{k=1}^{K} \pi_{iik}^{\alpha_{ik}} \in (0,1)$$

is the geometric average of country i's sector-level 'autarkiness ratios'. The welfare cost of returning to autarky, expressed as a proportion of current per capita GDP, can be parsimoniously computed as as a special case of the expression above:

$$\frac{\omega_i}{\omega_i^0} = \left(\frac{1}{\bar{\pi}_{ii}}\right)^{\frac{1}{\lambda\theta}}. \tag{23}$$

Only two parameters and K statistics are required to compute this measure. Both formulas above encompass the generalizations to multiple sectors due to Ossa (2015) and to endogenous employment (in an Armington model) due to Heid and Larch (2016). Observe in particular that ACR's gains from trade measure is *magnified* by a factor $1/\lambda > 1$, which is increasing in the elasticity of employment supply, $1 - \lambda$. Thus, as in Arkolakis and Esposito (2015), but for slightly different reasons since the mechanisms are different, gains from trade are always higher with an endogenous employment response than in models with inelastic labor and employment supplies.[23]

[22] If vacancy costs are paid in units of labor only ($\beta = 0$ in Appendix B) then the (un)employment rate is unrelated to the real wage in equilibrium ($\ell_i = \bar{\mu}_i$) because any change in wages translates into equiproportional changes in both the cost and benefit of opening a vacancy, leaving hiring decisions unchanged. The employment supply is inelastic.

[23] If vacancy costs are paid in units of labor only ($\beta = 0$ in Appendix B) then the expansion effect disappears. In turn, since employment no longer reacts to aggregate changes in prices, the magnification effect disappears from (23), which

Consider next the counterfactual domestic employment rate relative to its current level:

$$\frac{\ell_i'}{\ell_i} = \left(\frac{\omega_i'}{\omega_i}\right)^{1-\lambda} \left[1 - \frac{\mathrm{Cov}\left(s_{ik} - s_{ik}', \mu_{ik}\right)}{\bar{\mu}_i}\right], \tag{24}$$

where

$$\mathrm{Cov}\left(s_{ik} - s_{ik}', \mu_{ik}\right) \equiv \sum_{k=1}^{K} \left(s_{ik} - s_{ik}'\right)\left(\mu_{ik} - \bar{\mu}_i\right)$$

is the covariance between the sector-specific matching efficiencies and the shift in production shares. If the counterfactual is autarky then $s_{ik}^0 = \alpha_{ik}$ and $\mathrm{Cov}\left(s_{ik} - \alpha_{ik}, \mu_{ik}\right)$ is the covariance between the sectoral matching efficiencies and a theory-consistent measure of *revealed comparative advantage* of country i (indeed s_{ik} is greater than α_{ik} in exporting sectors whereas $s_{ik} < \alpha_{ik}$ holds in import-competing sectors).

Inspection of (24) reveals that two effects compete in the determination of the overall impact of a trade reform on the equilibrium employment rate in the open economy. First, as in the autarky equilibrium, an increase in the real wage has a positive partial effect on the employment rate. This *expansion effect* affects all sectors in the same way by (13): when a trade reform results in efficiency gains from trade, then such gains are associated with increased job creation and, in turn, higher real wages and lower equilibrium unemployment rates. Second, for given real wages, any reform that reallocates resources towards sectors with low labor market frictions relative to the domestic average (i.e. sectors such that $\mu_{ik} > \bar{\mu}_i$) results in a rise of employment ℓ_i – and vice-versa. This *reallocation effect* occurs because labor market frictions differ across labor submarkets.

This finding has important implications for trade policy and its accompanying measures. Though improved trade may result in the overall growth of national purchasing power, individual effects are heterogeneous. To the extent that gains from trade are not redistributed through unemployment benefits, there are winners and losers in terms of employment.[24] We further develop this theme in subsection 5.4 below.

Summarizing, we establish the following:

Proposition 2 (Gains from trade and unemployment). ***(i)*** *The trade equilibrium employment rate in country i (ℓ_i) is greater than its autarky employment rate (ℓ_i^0) if it has a revealed comparative advantage in sectors with relatively high matching efficiency:*

$$\mathrm{Cov}\left(s_{ik} - \alpha_{ik}, \mu_{ik}\right) > 0 \quad \Rightarrow \quad \ell_i > \ell_i^0.$$

(ii) *The actual equilibrium employment rate in country i (ℓ_i) is greater than the counterfactual employment rate (ℓ_i') if the actual allocation yields higher real wages and if it allocates more resources to*

collapses to Ossa's (2015) generalization of the ACR formula, $\omega_i/\omega_i^0 = \left(1/\bar{\pi}_{ii}\right)^{1/\theta}$. For any $\beta \in (0,1)$ the ACR formula is a convex combination of the former expression and of (23); Appendix B provides details.

[24]Note also that our real wage is measured in terms of *expected* real wage. Would the employment rate decrease, then individuals that retain their job would experience an even higher real wage growth than the national average.

sectors with high matching efficiencies than the counterfactual allocation does:

$$\frac{\omega_i}{\omega_i'} > 1 \quad and \quad \mathrm{Cov}\left(s_{ik} - s_{ik}', \mu_{ik}\right) > 0 \quad \Rightarrow \quad \ell_i > \ell_i'.$$

Proof. The proof of (**ii**) is by inspection of (24); (**i**) is a corollary of (**ii**) and follows from the fact that $\omega_i/\omega_i^0 > 1$ by Samuelson (1962) and Kemp's (1962) Gains From Trade theorems; in our model, an exact, parsimonious formula for ω_i/ω_i^0 is available in equation (23). ∎

The second part of (**ii**) above generalizes Proposition 6 (iii) of Helpman and Itskhoki (2010) to a multi-sector environment with comparative advantage. Of course, this Proposition leaves open a situation – which is novel and does not occur in the aforementioned papers – in which the counterfactual allocation is associated with both a higher level of average real wages and a higher unemployment rate. A necessary condition for this to occur is that resources be reallocated towards sectors with low matching efficiencies.

Finally, note that if comparative advantage is determined purely by country-sector specific production technologies (the φ_{ik}'s), which is the case if e.g. $\mu_{ik} = \mu_i\mu_k$, all i and k, then the s_{ik} do not depend on labor market frictions by (19), (20), and (21). In this case, all else equal, countries that enjoy a purely technological comparative advantage in high-μ_k sectors end up with a relatively high employment rate at equilibrium.

5.4 Welfare and 'Stolper-Samuelson effects'

In our model, workers are homogeneous ex ante but are heterogeneous ex post: some are unemployed and earn a wage while the rest are unemployed. Assessing effects of trade reforms on the average real wage only thus provides an incomplete picture of the full welfare effects. Conversely, many a policymaker emphasize the (un)employment effects of trade reforms with scant consideration for the real wage effects. We bridge the gap between these polar views by using the following welfare criterion:

$$\mathbb{W} = \frac{\omega}{u^{\xi}},$$

where $\xi \in \mathbb{R}_+$ is a parameter governing society's aversion to unemployment. In Appendix C, we provide microeconomic foundations to this expression. In particular, we show how a society that is *averse to inequality* naturally ends up being *averse to unemployment* in equilibrium. Individual risk aversion behind a 'veil of ignorance' is a standard way of justifying societal inequality aversion since at least Atkinson (1970); we pursue this route in Appendix D and show that societal aversion to inequality and individual risk aversion are isomorphic in this context. In the limit $\xi \to 0$, society is neutral towards inequality and cares only about the average real wage. This corresponds to the Benthamite social welfare function. Conversely, in the limit $\xi \to \infty$, society is so inequality-averse that it aims at minimizing the number of low income earners (here, the unemployed). This corresponds to the Rawlsian social welfare function. In our quantitative analysis, we assess the welfare effects of counterfactual policy reforms by putting an equal weight to average real wages and unemployment rates, namely we set $\xi = 1$, so that

$$\frac{\mathbb{W}'}{\mathbb{W}} - 1 = \frac{\omega'/u'}{\omega/u} - 1 \approx \frac{\omega'}{\omega} - \frac{u'}{u}. \tag{25}$$

In Appendix C, we show that changes in welfare as measured by this criterion are identical to changes in Atkinson's (1970) social welfare function with a societal constant rate of inequality aversion equal to two.[25] To summarize, we have shown:

Proposition 3 (Welfare, aggregate unemployment, and the gains from trade). *Let us assess welfare changes using the $\mathbb{W}$-criterion. Then **(i)** if society is neutral to inequality ($\xi = 0$) then maximising social welfare requires maximizing the average real wage and a trade reform is desirable if and only if it raises the average real wage; **(ii)** if society is averse to inequality ($\xi > 0$) then a trade reform is desirable if it simultaneously raises average real wages and reduces unemployment; it is undesirable if it reduces ω and increases u.*

Proof. (**i**) Immediate by $\lim_{\xi \to 0} \mathbb{W} = \omega$. (**ii**) Immediate from the definition of $\mathbb{W} \equiv \omega/u^{\xi}$. ■.

Discussion. A trade reform that raises real wages may be undesirable in a society that is averse to income inequality if this reform is associated with a sufficiently large increase of the unemployment rate. This intuitive finding has important implications for trade policy and its accompanying measures. Though more open trade may result in the overall growth of national purchasing power, there are heterogeneous effects among individuals. To the extent that trade gains are not redistributed through unemployment benefits, there are winners as losers in terms of employment, earnings, or both.

Our model may also feature a magnifying effect similar to a Stolper-Samuelson effect: consider a trade reform that leads to an increase in both u and ω; it follows that at least some of the workers who are employed both before and after the trade reform see their real wage increase by more than the average. Conversely, if the trade reform leads to a fall in both u and ω then at least some workers see their real wage fall by more than the average. To see this, note that sectoral employment rates all move in the same proportion by (13). In turn, sectoral wages move in the same proportion by (12). Thus, if both the unemployment rate u and the average per capita income ω rise then it must be that the per capita income of *employed* workers, $\omega/(1-u)$, rises proportionally more than ω. Thus, fewer people are employed and those that remain employed enjoy a rise in their real income that is larger than the average per capita income gain and those that loose their job endure a real loss, as was to be shown. Such 'Stolper-Samuelson' effects are frown upon in inequality-averse societies.

[25] Empirically, Stern (1977) (for the UK) and Young (1990) (for the US) find degrees of inequality aversion in the range $[1.61 - 1.97]$. In Appendix C, we also show that Sen's (1976) alternative welfare criterion puts much less weight on unemployment changes than Atkinson's.

6 Estimation methodology

In this section we take our model to the data. We proceed first by estimating the labor market frictions and use these estimates to quantify the welfare and employment consequences of implementing three counterfactual scenarios in Section 7.

6.1 Data

Bilateral sector-level trade data are obtained for 181 exporting countries and 139 importing countries in year 2008 from CEPII's BACI database. Bilateral sector-level tariffs are taken from UNCTAD's TRAINS database. Country-pair and internal distances as well as other gravity-type variables are from CEPII's gravity database. The regional trade agreement RTA dummy is computed using the bilateral database available from Jeffrey Bergstrand's website (May 2013 version). Trade balance data for year 2008 are sourced from World Bank Development Indicators (WDI) database. Sectoral production data is taken from OECD's Stan database (ISICRev3). Table 1 lists the sectors. Data are classified into 35 ISICRev3 sectors, out of which 24 produce tradable goods (those coded 1 to 37 in Table 1).[26] The ILO reports yearly country-level employment rates in its Key Indicators of the Labor Market (KILM) database. We also use the KILM data to compute sector-specific unemployment rates in each country for 15 sectors. In computing the sector-specific unemployment rate, we use the number of unemployed persons whose previous employment was in that sector (see footnote 28 below for details). Data on both sector-specific unemployment and sectoral production are available over the period 2001-2008 for a set of 25 OECD countries, henceforth 'OECD-25'.[27] The Bureau of Labor Statistics (BLS) provides unemployment rates for disaggregated manufacturing sectors in the US. No other country provides unemployment data at this level of sector disaggregation.

6.2 Empirical strategy

We aim to quantify the employment consequences of any given counterfactual. For convenience, we rewrite (24) as

$$\frac{\ell_i'}{\ell_i} = \left(\frac{\omega_i'}{\omega_i}\right)^{1-\lambda} \frac{\bar{\mu}_i'}{\bar{\mu}_i}, \tag{26}$$

where $\bar{\mu}_i \equiv \sum_k s_{ik}\mu_{ik}$ and $\bar{\mu}_i' \equiv \sum_k s_{ik}'\mu_{ik}$.

[26] We classify sectors according to availability of sectoral unemployment rates. There are 15 aggregate sectors categorised at ISICRev3 Section-level (i.e. 1-digit level) according to data availability, including the manufacturing sector. The 21 manufacturing subsectors without available data are disaggregated to the Division-level (i.e. 2-digit level). This results in a total of 35 sectors.

[27] These countries are (in increasing order of PPP GDP per capita): Mexico, Poland, Hungary, Republic of Korea, Czech Republic, Israel, Portugal, Slovenia, Greece, New Zealand, Spain, France, Iceland, Japan, United Kingdom, Italy, Finland, Canada, Germany, Belgium, Sweden, Austria, Denmark, United States, and Switzerland.

Data on the actual sectoral production shares s_{ik} and on real per capita GDP are readily available for the OECD-25 countries. However, there does not exist any comprehensive and detailed data on country- and sector-specific labor market frictions so that the μ_{ik}'s need to be estimated. We also estimate the counterfactual values for the sectoral production shares s'_{ik} and real per capita GDP ω'_i. For this purpose (i) we use the largest available sample of countries to estimate trade costs and elasticities and to simulate worldwide counterfactual trade flows and (ii) we compute the counterfactual sectoral production shares and real per capita GDP for the OECD-25 countries with available sectoral production and unemployment data. In the rest of Section 6 we estimate in turn the matching efficiencies, μ_{ik} (subsection 6.3), and the elasticity of trade to delivery costs, θ (subsection 6.4). We start with the estimation of the μ_{ik}'s.

6.3 Estimation of sector-specific matching efficiencies

Identifying assumption. Our identifying assumption is that the country and sector components of μ_{ik} are multiplicatively separable. Our data feature a panel dimension; adding time subscripts to our variables, we thus impose $\mu_{ikt} = \mu_{it}\mu_k$, for all i, k, and t, that is, matching efficiencies are country-time- and sector-specific. Countries with labor market institutions that are more favorable to job creation tend to have higher μ_i's on average than countries with more rigid rules; the μ_{it}-specification allows for country-specific business cycles. Also, job creation and the matching of workers and firms are easier in sectors with a high μ_k than in sectors with a low μ_k across countries and time.

Our data does not allow us to identify country-sector components of μ_{ik} (though we do identify country and sector components separately). Several papers in the literature surveyed by Nunn and Trefler (2014), including Cuñat and Melitz (2012) and Helpman and Itskhoki (2010), emphasize that sector-specific labor market frictions interact with country-specific institutional characteristics to give rise to an independent source of comparative advantage, a possibility that is ruled out by our identifying assumption. Fortunately, three elements significantly reduce (and possible annihilate) the restrictiveness of this assumption. The first element is qualitative: the first-order effect of the reallocation channel that is central to the mechanism of our model does not rely on the interaction between the country and sector dimensions of μ_{ik}. The second and third elements are quantitative: Chor (2010) runs a kind of 'horse race' among several sources of comparative advantage; he finds that labor market institutions amount to the least variation among all sources of comparative advantage that he accounts for (other sources include financial market institutions, product market institutions, and relative factor endowments). Furthermore, Chor's conclusions are based on a large and heterogenous sample of 83 countries. Our sample of OECD countries features much more similar labor markets, reducing further the potential for country-specific labor market institutions to act as significant sources of comparative advantage. Below, we further estimate sector-specific matching efficiencies for different subsamples of OECD countries and obtain significant and large rank correlations among the vectors of μ_k estimated this way. All these lend support to the idea that our specification captures the first-order effects of our reallocation channel in a precise manner.

Estimation. We estimate the μ_k's as follows. We start with the sectors for which sector-specific unemployment rates are available (Table 1 provides a list). Taking logs of (13) and allowing for time variation yields

$$\ln \ell_{ikt} = \ln \left(\mu_{it} \omega_{it}^{1-\lambda} \right) + \ln \mu_k,$$

which can be estimated by running the fixed effect regression

$$\ln \ell_{ikt} = FE_{it} + FE_k + \text{error}_{ikt},$$

where the error term is measurement error in ℓ. Clearly, the sector matching efficiency μ_k's are recovered using the sector fixed effects FE_k. The dependent variable is computed using sectoral unemployment data for OECD-25 countries for the period 2001-2008, sourced from the ILO's KILM database, where ℓ_{ikt} is defined as one minus the sectoral unemployment rate.[28] Sectoral unemployment data is available for 15 aggregated sectors, of which one is the manufacturing sector. See Table 1 for details.

We turn next to sectors for which sector-specific unemployment rates are not available in our OECD-25 sample of countries at this level of disaggregation. There are 21 such sub-sectors and they are all manufactures; see Table 1. We do have access to the unemployment rates of the manufacturing sector as a whole for all OECD-25 countries, which we use to estimate the sector-specific matching efficiencies based on the definition of $\bar{\mu}$ in (22); The matching efficiency of the aggregate manufacturing sector is thus given by (omitting country and time subscripts for simplicity)

$$\bar{\mu}_{manuf} = \sum_{m=1}^{21} s_m \mu_m, \qquad \sum_{m=1}^{21} s_m = 1,$$

where s_m and μ_m are the (observed) production shares and the matching efficiencies (to be estimated) of the 21 manufacturing sub-sectors of interest, respectively.

We combine both steps and estimate the matching efficiency of each of the 35 sectors on our 1,624-large sample using non-linear least squares (such one-step estimation is more efficient than its two-step equivalent because it allows for correlation between the error terms of the two steps):

$$\ln \ell_{ikt} = FE_{it} + (1 - \mathbb{I}_k) FE_k + \mathbb{I}_k \ln \left(\sum_{m=1}^{21} s_{imt} \mu_m \right) + \text{error}_{ikt}, \tag{27}$$

where $\mathbb{I}_k$ is an indicator variable equal to unity when k is the aggregate manufacturing sector and to zero otherwise. Summarizing, the sample consists of 15 aggregate sectors, one of which is the aggregate

[28] There, sector-k unemployment rate is defined as $u_{ikt} = U_{ikt}/(U_{ikt} + H_{ikt})$, where H_{ikt} is the number of workers currently employed in sector k and U_{ikt} is the number of workers who are currently unemployed and whose last job was in sector k. This definition of sectoral unemployment is the exact empirical counterpart of u_{ikt} in our static model, where u_{ikt} is the fraction of workers searching for a job in sector k but unable to form a match, i.e. $u_{ikt} = 1 - \ell_{ikt}$.

manufacturing sector; 21 disaggregated manufacturing sub-sectors (the m's); 25 OECD countries (the i's); and eight years between 2001-2008 (the t's). In what follows, we refer to μ_k as the vector of matching efficiency estimates for the set of all 35 sectors (14 aggregate sectors and 21 disaggregated manufacturing sub-sectors).

Table 2, column 3, reports our estimates of sector-specific matching efficiencies, while Figures 2 and 3 provide a graphical representation. The μ_k's are precisely estimated and our parsimonious specification explains a large fraction of the variance in the data (adjusted $R^2 = 0.6$).[29] Lowest significant estimates of μ_k's are for sectors 'Coke, refined petroleum products and nuclear fuel', 'Other transport equipment' and 'Other miscellaneous manufacturing', with μ_k's of 0.66, 0.72 and 0.85, respectively. The highest μ_k estimate is 1.49 for both 'Non-metallic mineral products' and 'Printing and publishing.' To put these estimates into context, they would imply that in each country the sectoral employment rate in 'Coke, refined petroleum products and nuclear fuel' sector is 11% lower than in the reference sector of 'Agriculture, hunting and forestry', while in 'Printing and publishing' it is 55% higher relative to the same reference sector.

These sector-specific matching efficiencies have high predictive power: decomposition of the standard deviation of $\ln(\ell_{ikt})$ into between and within components reveals that the within country-time component (i.e. variation across products) dominates. Hence, these sector specific properties are not only statistically significant but also highly relevant in determining the overall rate of unemployment.

External validity and alternative estimations. The μ_k's play an important role in our theory and in the quantitative illustrations below. It is thus important to evaluate to which extent we can trust that they reveal something fundamental about the OECD countries in our sample. We perform several exercises to this aim.

1. We test the external validity of our matching efficiency estimates for the manufacturing sub-sectors using Bureau of Labor Statistics (BLS) data; these data contain employment rates across a set of disaggregated manufacturing sub-sectors for the US. Under the joint null hypothesis that our model is the data generating process and that our identifying assumption $\mu_{imt} = \mu_{it}\mu_m$ holds, we expect the available BLS sector-specific US employment rates, $\ell_{US,mt}$, to correlate well with our matching efficiency estimates computed from our OECD-25 sample of countries, $\hat{\mu}_m$.[30] Table 3 reports the results. The patterns displayed in Table 3 and illustrated in Figure 1 are supportive of this hypothesis on three counts. First, the correlation and rank correlation between $\ell_{US,mt}$ and $\hat{\mu}_m$ are strong (about 0.65 on average). Second, since these correlations are between US observables and OECD-wide estimates,

[29] All estimated μ_k's are positive and most are significant at the 1% significance level. The few sectors with insignificant estimates ('Wearing apparel', 'Wood', 'Rubber and plastics products', and 'Medical, precision and optical instruments') amount to about only 10 % of production across OECD countries. Therefore, they are not a key driver of the reallocation effect on the overall unemployment rate.

[30] The BLS database includes a decomposition of employment rates for 12 manufacturing sectors across several years. Some of our 21 μ_m's are therefore aggregated to correspond to the 12 BLS manufacturing sectors, by computing the weighted averages over the relevant sub-sectors, where the weights are the US production shares in the relevant years.

they suggest that matching efficiencies display no systematic sector-country component. Third, this correlation is stable over the years 2005-2009, which rules out sector-time variations. This is the case even for 2009, an out-of-sample and arguably atypical year. The quasi-parallel shifts in the linear fits for years 2007, 2008 and 2009 reported in Figure 1 suggest that our sector-specific labor matching efficiencies are pro-cyclical, as are Barnichon and Figura's (2015) estimates of the aggregate matching function.

2. We split our OECD-25 sample of countries into 'high-income' and 'low-income' countries, where income is defined as purchasing power parity GDP per capita.[31] We re-estimate the matching efficiencies of the 35 sectors for each sub-sample of countries separately. The correlation between the two estimated vectors of μ_k is significant and large, at around 0.8 (rank correlation 0.65). Our sector-specific matching efficiency estimates are thus stable across high- and low-income countries. This finding lends further support to our identification hypothesis.

3. We split our original sample period 2001-2008 into pre- and post-2005 sub-samples and re-estimate the matching efficiencies of the 35 sectors for each sub-period separately. The correlation between the two estimated vectors of μ_k is significant and large, at around 0.7 for both the correlation and rank correlation. Our sector-specific matching efficiency estimates are thus stable over time, which lends further support to our identification hypothesis.

4. We perform a more general out-of-sample validity check for 14 OECD countries for which data is available for year 2011. In this test we compare the observed evolution of country-level employment rates to the one predicted by our model between 2008 (the base year) and 2011. In all counterfactual exercises of Section 7, we use equation (26) to predict the 2011 employment rate relative to the 2008 employment rate. To this purpose we make use of a convenient property of our model whereby the relative employment rates across sectors are constant, such that the expansion effect must equal the relative change in sectoral employment rates of any sector, i.e. $(\omega_{it'}/\omega_{it})^{1-\lambda} = (\ell_{ikt'}/\ell_{ikt})$ for any k. We can thus rewrite equation 26 as:

$$\forall\, k = 1, ..., 35 : \qquad \frac{\ell_{i,2011}}{\ell_{i,2008}} = \frac{\ell_{ik,2011}}{\ell_{ik,2008}} \frac{\bar{\mu}_{i,2011}}{\bar{\mu}_{i,2008}}. \tag{28}$$

For each country, we approximate the expansion effect (the first term on the right-hand side) by the median of the 2011-to-2008 ratios in sectoral employment rates. The reallocation effect (the second term of the right-hand side) is computed using our estimated values of μ_k and the observed production shares s_{ik} in years 2008 or 2011, whichever is relevant. Figure 6 juxtaposes the observed country-level employment rate ratios to (i) the expansion effect, in black dots (one for each country), and (ii) the overall 2011-to-2008 predicted ratios in country-level employment rates that combine the expansion and the reallocation effects as per (28), in grey dots. We plot the 45°-line and report 90% confidence

[31] Iceland is the median country by this measure; among OECD-25 countries, 'low-income' countries are countries from Mexico up to France on the list of footnote 27; 'high-income' countries are countries from Japan to Switzerland on this list.

intervals for the predicted ratios of the overall employment rate.[32] Two main conclusions emerge. First, the overall out-of-sample prediction, based on our sector-specific matching efficiencies, does a good job. The observed ratio is included in the confidence interval of the predicted ratio in 9 cases out of 14. Second, the estimated reallocation effects systematically bring the expansion effect closer to the observed ratio (from black to grey dots), confirming that the reallocation channel is an important determinant of employment rates.

5. Finally, we propose to identify λ using an alternative specification of (27). Specifically, we take the identifying assumption one step further and impose an additional layer of multiplicative separability and let $\mu_{it} = \mu_i \mu_t$. The country-year fixed effects in (27) can then be decomposed as $FE_{it} = (1-\lambda)\ln\omega_{it} + \ln\mu_i + \ln\mu_t$, where ω_{it} is the real per capita GDP, and $\ln\mu_i$ and $\ln\mu_t$ are recovered using country and year fixed effects, respectively. We obtain (i) an estimate of λ of 0.85 (with a clustered standard error of 0.028), and (ii) a new 35-row vector of μ_k estimates, which are highly correlated with (but less precise than) those obtained from the original estimation of (27) (rank correlation of around 0.9). For this reason, in the remainder of the paper we use the original set of μ_k estimates reported in Table 2, obtained using the less stringent identifying assumption supporting the estimation of (27). In what follows, we set the matching elasticity at $\lambda = 0.6$, which is the midpoint of Petrongolo and Pissarides' (2001) plausible range, and test the robustness of our main results for a range of values of λ between [0.3, 0.9] in Appendix G.[33]

6.4 Estimation of trade elasticities

We use a gravity equation to estimate the trade elasticity with respect to bilateral trade costs. Using expressions (19), (20), and (21), and taking logs yields

$$\ln E_{ijk} = -\theta \ln \tau_{ijk} - \theta \ln \kappa_{ik} - \ln \sum_{i'=1}^{I} \left(\tau_{i'jk}\kappa_{i'k}\right)^{-\theta} + \ln(\alpha_{jk}E_j), \tag{29}$$

where E_{ijk} is the value of exports from country i to country j in sector k and

$$\kappa_{ik} \equiv \frac{w_i^{\lambda}\mathbb{P}_i^{1-\lambda}}{\varphi_{ik}\mu_{ik}} \tag{30}$$

captures exporter-sector unobservables. Note that $t_{ik} = \kappa_{ik}\tau_{ik}$ holds by definition of κ and t in (19) and (30). We assume that sector-specific bilateral trade frictions obey

$$\begin{aligned} \tau_{ijk} \;\; &\equiv \;\; (1+\text{tariff}_{ijk})D_{ij}^{\delta_D} \\ &\times \;\; \exp\left(\delta_{rta}RTA_{ij} + \delta_{cont}CONT_{ij} + \delta_{lang}LANG_{ij} + \delta_{colon}COLON_{ij} + \delta_{curr}CURR_{ij}\right), \end{aligned}$$

[32] Confidence intervals of the country medians are too narrow to be reported on the figure.

[33] The estimate of λ, at 0.85, is larger than conventional estimates of the labor share in the matching function. We show in the Appendix that both the introduction of labor costs into the vacancy cost (Appendix B) and the introduction of risk-aversion (in Appendix D) change the interpretation of the coefficient of the real per capita GDP; in both cases the coefficient of 0.85 is consistent with lower values of λ. See Appendices B and D for details.

where tariff_{ijk} is the ad valorem tariff rate that country j imposes on good k imports from i, D_{ij} is the (geodesic) bilateral distance between the economic capital cities of i and j, and the remaining variables are dummy variables such that $RTA_{ij} = 1$ if a regional trade agreement is in force between i and j, $CONT_{ij} = 1$ if countries share a common border, $LANG_{ij} = 1$ if a common language is spoken by at least 9% of the population of each country, $COLON_{ij} = 1$ if the country pair was ever in a colonial relationship, and $CURR_{ij} = 1$ if these countries share a common currency.

We can then rewrite expression (29) as a gravity equation:

$$\begin{aligned} \ln E_{ijk} &= \beta_{tariff} \ln(1 + \text{tariff}_{ijk}) + \beta_D \ln(D_{ij}) + \beta_{rta} RTA_{ij} + \beta_{cont} CONT_{ij} + \beta_{lang} LANG_{ij} \\ &+ \beta_{colon} COLON_{ij} + \beta_{curr} CURR_{ij} + FE_{ik} + FE_{jk} + \epsilon_{ijk}, \end{aligned} \tag{31}$$

where the regression coefficients relate to the structural parameters of the model as $\beta_{tariff} = -\theta$, $\beta_x = -\theta\delta_x$ for $x \in \{D, rta, cont, lang, colon, curr\}$, $FE_{ik} = -\theta \ln \kappa_{ik}$ and $FE_{jk} = -\ln \sum_{i'} (\tau_{i'jk}\kappa_{i'k})^{-\theta} + \ln(\alpha_{jk} E_j)$ are sector-exporter and sector-importer fixed effects, respectively, and ϵ_{ijk} is measurement error in E_{ijk}.

We estimate the coefficients of this gravity equation using our cross-section sample of 181 exporters, 139 importers, and the 24 tradable ISIC Rev3 sectors reported in Table 1 for our pre-crisis base year 2008. We obtain $\hat{\theta} = -\hat{\beta}_{tariff} = 3.17$ (See Appendix E on Gravity estimation for further estimates). These findings are in line with the meta-analysis of Head and Mayer (2014) and the estimates of Simonovska and Waugh (2014).[34]

Our model is block-recursive: the presence of labor market frictions does not influence estimation of the gravity regression. This useful property is not unique to our model; Heid and Larch's (2016) Armington trade model also features it.

7 Unemployment and welfare effects under various scenarios

In this section we illustrate the mechanisms at play in the model by computing a series of counterfactual exercises. Subsections 7.1, 7.2, and 7.3 report the counterfactual real wage, welfare, and unemployment effects of the Transatlantic Trade and Investment Partnership (TTIP), of the Trans-Pacific Partnership (TPP), and of balancing trade in all countries, respectively.

We compute counterfactual changes in real wages, unemployment rates, and welfare for both FTA scenarios (TTIP and TPP) under the assumption that tariffs and non-tariff barriers are eliminated among all FTA members in both agricultural products and manufactures. In the trade balance scenario

[34] The median and the mean coefficients of 744 statistically significant estimates (obtained from 32 papers) of the price elasticity in gravity regardless of the method are equal to -3.19 and -4.51, respectively (Head and Mayer, 2014). Simonovska and Waugh (2014) use a simulated method of moments to estimate $\hat{\theta}$ from disaggregate price and trade-flow data and find roughly -4. Our estimate of -3.17 is slightly lower due to the introduction of the RTA dummy which allows to control to some extent for non-tariff barriers to trade. When the RTA dummy is excluded, we obtain an estimate of -4.34 (see Appendix E for detailed estimation statistics).

(henceforth TB) we set the trade balance of each country in our database to zero. Under all scenarios, we compute the counterfactual wages, prices, and vectors of shares of workers allocated to each sector in all countries *taking account of general equilibrium effects*. This implies in particular that we allow the vector of exporter-sector unobservables obtained in the gravity regression, $\hat{\kappa}_{ik}$, to change endogenously within each policy experiment. We start by briefly describing the methodology for the FTA scenarios. Appendix F describes this methodology in detail. The method for the trade balance (TB) scenario is somewhat different and is also set out in Appendix F.

We let the initial equilibrium fit the current data as follows. We calibrate the vector of country-level production values, E_i^C, to minimize the sum of squares of the excess demands, denoted by ED_i:

$$ED_i \equiv \sum_{j=1}^{J} \sum_{k=1}^{K} \hat{\pi}_{ijk} \alpha_k E_j^C - E_i^C,$$

where $\hat{\pi}_{ijk}$ are estimates of market shares recovered from the gravity regression in (31) and the consumption shares α_k are calculated as sectoral production shares for the entire OECD region.

Let $\tilde{x} \equiv x'/x$ define the ratio of the counterfactual and actual values of any variable x. It then follows from (30) that $\tilde{\kappa}_{ik} = \tilde{\kappa}_i$ for all k. In Appendix F, we show that the counterfactual equilibrium can then be characterized by two unknown I-dimensional vectors $\tilde{\mathbf{E}}$ and $\tilde{\kappa}$, which can be jointly estimated by minimizing the sum of squares of the following two systems of equations:

$$\begin{aligned}
ED_i &\equiv \sum_{j=1}^{J} \sum_{k=1}^{K} \frac{\left(\hat{\tau}_{ijk}\hat{\kappa}_{ik}\right)^{-\hat{\theta}} \left(\tilde{\tau}_{ijk}\tilde{\kappa}_{i}\right)^{-\hat{\theta}}}{\sum_{i'} \left(\hat{\tau}_{i'jk}\hat{\kappa}_{i'k}\right)^{-\hat{\theta}} \left(\tilde{\tau}_{i'jk}\tilde{\kappa}_{i'}\right)^{-\hat{\theta}}} \alpha_k E_j^C \tilde{E}_j - E_i^C \\
e\tilde{\kappa}_i &\equiv \tilde{E}_i^{\lambda} \widetilde{\mathbb{P}}_i^{1-\lambda} - \tilde{\kappa}_i \\
&= \tilde{E}_i^{\lambda} \prod_{k=1}^{K} \left[\frac{\sum_{j=1}^{J} \left(\hat{\tau}_{ijk}\hat{\kappa}_{jk}\right)^{-\hat{\theta}} \left(\tilde{\tau}_{ijk}\tilde{\kappa}_{j}\right)^{-\hat{\theta}}}{\sum_{j=1}^{J} \left(\hat{\tau}_{ijk}\hat{\kappa}_{jk}\right)^{-\hat{\theta}}} \right]^{-\frac{\alpha_k}{\hat{\theta}}(1-\lambda)} - \tilde{\kappa}_i,
\end{aligned}$$

where all $\hat{x}$ variables are gravity estimates, the $\tilde{\tau}_{ijk}$'s are calculated by setting tariffs to zero and turning the RTA dummy to one for country-pairs that belong to the same FTA, and E_i^C is the vector of country-level expenditure values calibrated in the previous step. The first equation above is a trade balance condition. The second set of equations hold by definition of κ under the maintained assumption that technology parameters μ_{ik} and φ_{ik} are invariant. We solve this high-dimensional system of non-linear equations iteratively using Matlab.

The counterfactual trade flows are then aggregated at country-sectoral level to obtain the counterfactual production shares for each country, s'_{ik}. The change in the employment rates under the counterfactual equilibrium is an interaction of the expansion and the reallocation effects; using (26), we obtain:

$$\frac{\ell'_i}{\ell_i} = \left(\frac{\tilde{E}_i}{\widetilde{\mathbb{P}}_i} \right)^{1-\lambda} \frac{\sum_k s'_{ik}\mu_k}{\sum_k s_{ik}\mu_k}. \tag{32}$$

As explained in subsection 6.3, we set the matching elasticity at $\lambda = 0.6$ throughout all scenarios following Petrongolo and Pissarides (2001). We run sensitivity tests in Appendix G and our qualitative and quantitative results are quite robust to this parametrization.[35]

7.1 The Transatlantic Trade and Investment Partnership (TTIP) scenario

The Transatlantic Trade and Investment Partnership (TTIP) currently being negotiated between the European Union and the United States aims at removing trade barriers between the EU and the US (including tariffs, unnecessary regulations, and restrictions on investment). In this counterfactual exercise, we set all bilateral EU-US tariffs to zero and we switch on the Regional Trade Agreement dummy (as estimated from our gravity regression reported in Appendix E) among all TTIP countries.

We report the results for 28 OECD countries in Table 4 and Figure 4.[36] All values are in %. The top panel of Table 4 reports results for potential members of the TTIP (US and EU countries); the bottom panel reports results for a subset of OECD countries left out of the agreement. The first column displays the unemployment rate of the base year (2008); all other columns report predicted changes under the TTIP relative to the actual values in the base year. The second column reports the 'reallocation effect' which arises as a result of the reallocation of workers across sectors characterized by heterogeneous matching frictions. Changes in the unemployment rates are reported in the third column. The fourth column displays the estimated changes in real wages, namely, the 'expansion effect' (ω'/ω^{2008}). Finally, column 5 reports changes in welfare as measured by (25): it is approximately equal to the difference between columns 4 and 3. Figure 4 summarises our main results in terms of percentage changes in unemployment levels and real wages for both TTIP members (dark diamonds) and non-members (light triangles). Figure 4 also features an 'iso-welfare' line, defined as the combination of changes in real wages and unemployment levels that lead to a welfare change in (25) equal to zero. The mathematical expression of the iso-welfare line is given by $\omega'/\omega^{2008} = u'/u^{2008}$. Countries experiencing a combination of changes in unemployment and real wages above the iso-welfare line are better off under TTIP; countries with a combination of changes below the iso-welfare line are worse off.

Several results featured in Table 4 and Figure 4 are noteworthy. First, the magnitude of the predicted changes is small. One reason for this is that EU-US tariffs are already low to start with; another reason has to do with our using of trade data at a fine level of disaggregation and this tends to produce smaller quantitative effects than when using more aggregated data (Costinot and Rodríguez-

[35]If vacancy costs are paid in units of labor only ($\beta = 0$ in Appendix B) then there is no expansion effect and the (un)employment rate variation arises solely from the reallocation effect; in this case, (32) simplifies to $\ell_i'/\ell_i = \bar{\mu}_i'/\bar{\mu}_i$. For any $\beta \in (0, 1)$ the exponent of the first term in the right hand side of (32) is a function of β and λ; Appendix G runs sensitivity tests for different values of this exponent.

[36]We report results for our OECD-25 sample of countries as well as for Estonia, Netherlands and Norway, which have data on sectoral production shares, but no data on sectoral employment rates. We do not have access to production data at a sufficiently disaggregated industry level for the remaining 6 OECD countries or for the non-OECD countries, which prevents us from computing the reallocation effect and the overall unemployment effects for such countries.

Clare 2014).[37] We also include non-traded sectors, which tends to reduce estimates further.

Second, all countries signing the agreement benefit from higher real wages. By contrast, the effect on country-wide employment is highly heterogeneous, both in direction and magnitude. This appears clearly in Figure 4. Specifically, unemployment in the US is predicted to rise by 1.1% from a base rate of 5.9% in year 2008 but is predicted to drop in most EU countries. These results underline the key prediction of our theoretical framework: that gains from trade in terms of real wages and employment effects are not perfectly correlated. According to our simulations, countries specialising in relatively high-friction sectors experience an increase in their equilibrium unemployment rate under TTIP, as is seemingly the case for countries such as Belgium, Italy, the Netherlands, and the US. All these countries benefit from trade in terms of an increase in the real wage, but welfare as measured by our Atkinson welfare criterion in (25) is predicted to fall due to an offsetting increase in unemployment. In the German case, the unemployment and the real wage effects almost exactly cancel out.

Third, the real wage and unemployment effects are similarly diverse for countries that are excluded from TTIP and as such suffer from trade diversion. While most of these countries are predicted to experience a decline in real wages, some such as Switzerland, New Zealand, and Iceland do experience a reduction in unemployment and an increase in welfare according to our Atkinson welfare criterion.

Our welfare results are obviously sensitive to the choice of welfare criterion. An alternative powerful welfare criterion is due to Sen (1976). Appendix C computes the estimated TTIP welfare effects according to Sen's welfare criterion and compares them to the welfare changes as measured by Atkinson's criterion.

7.2 The Trans-Pacific Partnership (TPP) scenario

We perform the same exercise as above for an alternative free trade agreement, the so-called Trans-Pacific Partnership (TPP) freshly agreed upon on October 5$^{\text{th}}$, 2015 by 12 negotiating partners (Australia, Brunei Darussalam, Chile, Japan, Malaysia, New Zealand, Peru, Singapore, South Korea, Taiwan, Vietnam, and the United States). Real wage, unemployment, and welfare results are reported for our sample of OECD countries in Table 5.

Note first that all potential TPP members in our sample would experience a real wage increase (column 3, top panel), while excluded countries would feel decreasing but virtually unchanged real wages (column 3, bottom panel). The reallocation effect is heterogeneous for both groups of countries (column 1); this pattern is similar to the corresponding pattern of subsection 7.1. Unemployment is predicted to fall in all participating countries and to increase slightly in non-participating countries

[37] For instance, our real wage effects are lower than those reported in Felbermayr, Heid, Larch, and Yalcin (2015) who use a one-sector framework. In the same vein, Costinot and Rodriguez-Clare (2014) simulate the real wage effect of the imposition of a unilateral US tariff of 40% across the board assuming that all tariffs are zero in the initial equilibrium. They find an average world real wage effect of -0.2% in the one sector framework and -0.14% when allowing for multiple sectors.

(column 2). As a result, the welfare effects of column 4 are unambiguously positive for participating countries and negative for the excluded ones.

Second, in comparison to the TTIP scenario, the US would benefit less from the TPP in terms of real wages. However, as unemployment is predicted to decrease slightly under TPP, the overall welfare effect for the US is positive under TPP, while it was negative under TTIP.

Finally, trade diversion effects seem to be at work. Japan – which is excluded from TTIP but is a would-be member of TPP – would be better off under the latter (+0.2%) than under the former agreement (+0.01%) in terms of real wage. By the same token, Canada, which experiences an almost 4%-unemployment decrease and a slight real wage increase under TPP, would also be better off than under either the status quo or TTIP (which leads to a reduction of its real wage and an increase of its unemployment rate). By the same logic, many EU countries are made (slightly) worse-off under TPP relative to the status quo (while most are better-off under TTIP).

7.3 The trade balance scenario

At no point in time is trade balanced in any country (Dekle, Eaton, and Kortum 2007; Eaton, Kortum, and Neiman 2013). Our aim here is to estimate the unemployment and welfare effects of eliminating trade imbalances. We do so by setting the trade balance of all countries in our database to zero.[38]

Several features of the results reported in Table 6 are noteworthy. First, our results are comparable to real wage changes reported by Dekle, Eaton, and Kortum (2007) (DEK henceforth). They obtain a change of -0.5% for the US based on its 2002 current account deficit, which is to be contrasted with our -0.3% based on our 2008 trade deficit data. In the same way, like them, we obtain positive real wage effects for Canada and Germany. The magnitude of the real wage effects that we find is larger than theirs (they obtain 0.5% and 0.2%, respectively). This is likely the result of two differences between our approach and theirs: first, the elasticity of trade volumes with respect to tariffs that we obtain from our gravity regression, −3.17 when we include standard gravity dummies, is in line with the estimates of Simonovska and Waugh (2014) but smaller in absolute value than the elasticity used in the published version of DEK, −8.28. Second, trade deficits are higher than current account deficits for most OECD countries so that eliminating trade deficits requires larger corrections than eliminating current account deficits.

Second, virtually all deficit countries experience a rise in unemployment (Italy is the only exception) ranging from a relatively small 2% for the US to a staggering 47% for Greece and 48% for Estonia. Closing these deficits implies reducing local consumption and, as this consumption is home-biased due to trade costs, this hurts real wages and reduces employment. All these countries also experience a fall in the average real wage by up to 5% in Portugal and Estonia, which yield substantial welfare reductions.

[38]We set the value of consumption equal to the value of production for each country and allow for general equilibrium effects.

Third, most surplus countries experience a fall in unemployment – sometimes substantial, at 71% for Norway – and a rise in real wages (almost 5% for Norway and Ireland). But some surplus countries – Austria, the Czech Republic, Denmark, and Japan – are made worse off.

Finally, the magnitude of the effects here are much larger than that of creating free trade areas. This result was to be expected because some imbalances are large (Norway has a surplus of almost 20% of GDP while Greece has a deficit of 18% of GDP in 2008) while remaining trade frictions in OECD countries are small.

8 Conclusion

This paper has introduced a multi-country, multi-sector general equilibrium model with international trade and labor market matching frictions. The equilibrium frictional unemployment rate of each country depends on the patterns of trade. The model features an expansion effect: when trade openness is associated with higher real wages, as is the case if the terms-of-trade effects are non-negative, then such gains translate into more job openings and lower equilibrium unemployment rates. The model also features a reallocation effect: ceteris paribus, the unemployment rate increases if the trade reform achieves a reallocation of resources towards labor market friction-intensive sectors, and conversely if sectors with relatively high labor market frictions contract and sectors with relatively high matching efficiency expand following this trade reform. A companion paper (Carrère, Fugazza, Olarreaga, and Robert-Nicoud, 2014) provides evidence for this effect.

Sector-specific labor market frictions play an important and original role in our model. We estimate these frictions in a structural way using OECD data and find that they correlate well with observed US-sectoral employment rates for which the BLS provides data. We also find that the global economic crisis that started in 2008 ended up affecting unemployment in all sectors in the same proportions, which is consistent with our formulation of the labor market frictions.

Policymakers are usually at least equally interested in the (un)employment effects of trade reforms as in the (real) wage effects. By explicitly allowing for equilibrium unemployment, our model addresses such concerns head on. We emphasize the circumstances under which both the employment and the real wage effects are aligned and – more importantly – when they are not. Such qualitative results are insightful but incomplete. We thus introduce welfare criteria based on Atkinson (1970) (and also Sen, 1976) to arbitrage between the two effects when they work in opposite directions.

In our model, workers are risk neutral even as society is averse to inequality. A popular way of founding the latter is to replace the former assumption by assuming instead that workers are risk averse. A natural extension of our framework would do just that and evaluate to what extent this additional margin requires amendment of the ACR gains-from-trade formula and of our employment variation formula in (22). We speculate that a first order quantitative effect of risk aversion is to interfere with the sector choice of workers and, therefore, with the reallocation effect of trade on (un)employment.

A different potential venue for future research in the area is to acknowledge the rise in importance of global value chains and to perform a similar exercise using data on value added. As is well known, the elasticity of welfare with respect to trade openness increases when accounting for input-output linkages among sectors (Costinot and Rodríguez-Clare, 2014).

By featuring an arbitrary number of countries and sectors and being highly tractable, our model is readily amenable to empirical applications and quantitative evaluations of fictional policy experiments. We illustrate with two specific global free-trade agreements currently in the making, TTIP and TPP, and with the re-balancing of global trade imbalances. We obtain small real wage and unemployment effects in the former case and substantial effects in the latter. The model could also be used to study the effects of other scenarios, such as 'Brexit' or 'Greexit.'

Appendix A: Profession-specific labor market frictions

Assume that each of the K sectors in the economy combine $S \geq K$ different skills or occupations to produce their output and that each worker makes a sunk occupational choice. To simplify the analysis and make the connection with our setting in the main text more direct and straightforward, we assume that each of the S occupations is organized as a sector that produces under perfect competition and sells its output to the K final good sectors in a competitive fashion. In turn, each occupation hires workers in an occupation-specific labor submarket impeded by labor market frictions.

Production

The production function of variety x in sector k is now given by

$$\mathbb{Q}_{ik}(x) = \varphi_{ik}(x) \prod_{s=1}^{S} H_{iks}(x)^{a_{ks}}, \quad \text{where} \quad \sum_{s=1}^{S} a_{ks} \equiv 1,$$

$H_{iks}(x)$ is the mass of workers of occupation s implicated in the production of variety x in sector k, and a_{ks} is the sector-occupation Cobb-Douglas coefficient.

The production function of occupation s is linear: its output is equal to the mass of workers being hired in that occupation, H_s. Occupation firms face an occupation-specific cost of hiring a worker, which is equal to

$$c_{is} \equiv \mathbb{P}_i \left(\frac{\ell_{is}^{\lambda}}{\mu_{is}} \right)^{\frac{1}{1-\lambda}} \tag{33}$$

where ℓ_{is} is the employment rate of occupation s in country i.

Wage bargaining

Once matched, the firm and the worker bargain over a firm-occupation-specific wage for a given occupation $w_{iks}(x)$ in order to split the rent (we abuse notations and use x here to denote the variety of an arbitrary occupation firm). Taking all prices as given, and assuming equal bargaining weights, the wage is then equal to

$$w_{iks}(x) = \frac{1}{2}\frac{a_{ks}E_{ik}(x)}{H_{iks}(x)}.$$

Firms find it optimal to hire workers until the firm-specific equilibrium wage for a worker of a given occupation is equal to the cost of replacing the worker c_{is}. It follows then, that all workers in a certain occupation are paid the same occupation-specific wage which is constant across sectors:

$$w_{iks}(x) = w_{is} = c_{is}. \tag{34}$$

Labor market

Matching frictions are occupation-specific. Firms post vacancies in the occupation-specific job submarket, so that our parameter of interest (the occupation-specific matching efficiency net of vacancy cost) is given by $\mu_{is} = \tilde{\mu}_{is}/v_{is}^{1-\lambda}$, where μ_{is} is the occupation-specific matching TFP and v_{is} is the vacancy cost specific to the occupation s.

Workers freely choose the occupation they want to specialize in and that choice is sunk. The no-arbitrage condition then becomes:

$$w_i = \ell_{is} w_{is}. \tag{35}$$

Combining this expression with (33) and (34) yields:

$$\frac{w_i}{\mathbb{P}_i} = \left(\frac{\ell_{is}}{\mu_{is}}\right)^{\frac{1}{1-\lambda}}. \tag{36}$$

This implies that occupations with high matching efficiency μ_{is} have higher employment rate and, by the no-arbitrage condition (35), lower wages.

It follows in turn that the ratio of any pair of occupations in any sector is constant and equal to

$$\forall s, \tilde{s} : \frac{H_{iks}}{H_{ik\tilde{s}}} = \frac{a_{ks}}{a_{k\tilde{s}}}\frac{\mu_{is}}{\mu_{i\tilde{s}}}. \tag{37}$$

That is to say, firms hire relatively more workers from occupations with high matching efficiency and a high weight in the production function. These ratios are sector-specific and exogenous.

Sectoral averages

We now proceed to aggregate wages and employment rates at the sector level (as in the model in the main text). We show that all sector-specific quantities reflect sectoral averages of the respective variables.

We first show that, for each sector-occupation pair, the shares of hired workers, $H_{iks}/\sum_{\tilde{s}} H_{ik\tilde{s}}$, and the shares of workers looking for work, $L_{iks}/\sum_{\tilde{s}} L_{ik\tilde{s}}$, are constant by (37). Specifically:

$$h_{iks} \equiv \frac{H_{iks}}{\sum_{\tilde{s}} H_{ik\tilde{s}}} = \frac{\mu_{is}a_{ks}}{\sum_{\tilde{s}} \mu_{i\tilde{s}}a_{k\tilde{s}}} \tag{38}$$

and

$$\frac{L_{iks}}{L_{ik\tilde{s}}} = \frac{a_{ks}}{a_{k\tilde{s}}}$$

such that the share of workers of a given occupation s looking for work in sector k is constant and given by:

$$s_{iks} \equiv \frac{L_{iks}}{\sum_{\tilde{s}} L_{ik\tilde{s}}} = a_{ks}. \tag{39}$$

Given these constant shares, we can now prove that key equilibrium conditions of our original sector-specific model still hold in the form of sectoral averages.

Proof of equation (13) in original model: It follows from (36) and (39) that the average employment rate in a sector k is equal to:

$$\begin{aligned} \bar{\ell}_{ik} \equiv \sum_{s=1}^{S} s_{iks}\ell_{is} &= \left(\frac{w_i}{\mathbb{P}_i}\right)^{1-\lambda} \sum_{s=1}^{S} a_{ks}\mu_{is} \\ &= \left(\frac{w_i}{\mathbb{P}_i}\right)^{1-\lambda} \bar{\mu}_{ik}, \end{aligned} \tag{40}$$

where $\bar{\mu}_{ik} \equiv \sum_s a_{ks}\mu_{is}$ is the average sectoral matching efficiency in equilibrium; it is constant and a function of parameters only.

Proof of equation (12) in original model: There exists an average sectoral-wage $\bar{w}_{ik}$ which is defined as follows, and obtained by substituting in expressions (33), (34) and (38):

$$\begin{aligned} \bar{w}_{ik} \equiv \sum_{s=1}^{S} h_{ks}w_{is} &= \frac{1}{\bar{\mu}_{ik}} \sum_{s=1}^{S} \mu_{is}a_{ks}w_{is} \\ &= \frac{1}{\bar{\mu}_{ik}} \mathbb{P}_i^{1-\lambda} w_i^{\lambda}. \end{aligned}$$

Combining with (40) we then obtain $\bar{w}_{ik}\bar{\ell}_{ik} = w_i$.

It then follows that all of the results of the original sector-specific model hold, where the sector-specific quantities are interpreted as sectoral averages.

Appendix B: Vacancy cost

In this appendix we develop the model under the assumption that the unit vacancy cost v_{ik} is a Cobb-Douglas combination of the domestic consumption bundle $\mathbb{U}_i$ and labor such that the per worker hiring cost is equal to $\mathbb{P}_i^{\beta} w_{ik}^{1-\beta} \nu_{ik} V_{ik}/H_{ik}$, some $\beta \in [0,1]$. The main text works with the special case $\beta = 1$, namely, vacancies use the final good only. As will become clear below, while some results are qualitatively altered in the polar case $\beta = 0$, all qualitative results and most quantitative results of the main text go through for any $\beta \in (0, 1]$. Under this generalized assumption, and making use of (6), (7), (9), and(11), the sectors-specific wage and per-worker hiring cost in (8) and (11) become

$$c_{ik} = w_{ik} = \mathbb{P}_i \left(\frac{\ell_{ik}^{\lambda} \nu_{ik}^{1-\lambda}}{\tilde{\mu}_{ik}} \right)^{\frac{1}{1-\lambda-\zeta}}, \tag{41}$$

where $\zeta \equiv (1-\lambda)(1-\beta)$ is a convenient collection of parameters such that $\zeta = 0$ if $\beta = 1$ and $0 \leq \zeta \leq 1 - \lambda$, $\forall \beta$. Combining this expression with the no-arbitrage condition (12), the expected/average real wage in (13) and the matching efficiency in (9) become

$$\omega_i \equiv \frac{w_i}{\mathbb{P}_i} = \left(\frac{\ell_{ik}}{\mu_{ik}} \right)^{\frac{1-\zeta}{1-\lambda-\zeta}} \quad \text{and} \quad \mu_{ik} \equiv \left(\frac{\tilde{\mu}_{ik}}{\nu_{ik}^{1-\lambda}} \right)^{\frac{1}{1-\zeta}},$$

respectively, which simplify to the corresponding expressions in the main text under the assumption $\zeta = 0$. Solving for ℓ_{ik} and plugging the resulting expression into (41) yields $w_{ik} = c_i/\mu_{ik}$, where the expression for the equilibrium 'input cost' in country i becomes

$$c_i = \left(\mathbb{P}_i^{1-\lambda-\zeta} w_i^{\lambda} \right)^{\frac{1}{1-\zeta}}.$$

Bilateral trade flows (in value) at the industry level still obey the familiar gravity equation, namely, (21) in the main text. By the same token, the production and labor shares of sector k in country i are still equivalent and equal to

$$s_{ik} \equiv \frac{L_{ik}}{L_i} = \frac{E_{ik}}{E_i}$$

by the no-arbitrage condition.

The aggregate employment rate in (22) becomes

$$\ell_i = \omega_i^{1-\frac{\lambda}{1-\zeta}} \bar{\mu}_i.$$

The expansion effect, defined as $\partial \ell / \partial \omega$ in the expression above, is monotonically decreasing in ζ and disappears if vacancies are paid in labor only; indeed, we obtain $\lim_{\zeta \to 1-\lambda} \ell_i = \sum_k s_{ik} \mu_{ik}$. In this case, any change in wages translates into an equivalent change in both the cost and the benefit of opening the vacancy, as such leaving hiring decisions unchanged. Importantly, for any $\beta \in (0, 1]$, and with the exception of the expansion effect, all estimation steps and all quantitative results remain unaffected by this generalization. Put differently, the modified matching efficiency in this model is irrelevant to both quantitative and qualitative results. This possible overestimation of the expansion effect matters in the counterfactual exercises, based on setting the value $\lambda = 0.6$ in the original model (which corresponds to setting $\lambda/(1-\zeta) = 0.6$ in the generalized model). However, as report in Table 8, the direction of our results is robust to a wide range of values of this exponent.

Finally, the generalization of the ACR formula for the gains from trade becomes

$$\frac{\omega_i'}{\omega_i} = \left(\frac{\bar{\pi}_{ii}'}{\bar{\pi}_{ii}} \right)^{-\frac{\beta}{\lambda\theta} - \frac{1-\beta}{\theta}}. \tag{42}$$

Inspection of the expression above reveals that the magnification effect of the ACR gains from trade in (23) is a by-product of the expansion effect: if vacancies use labor only then $\beta = 0$ and the formula above collapses to Ossa's (2015) multi-sector extension of the ACR formula. At the other extreme, if $\beta = 1$ then (42) simplifies to (23) in the main text, which is itself a generalization of Heid and Larch's (2016) ACR formula. For any other $\beta \in (0, 1)$ the generalized ACR formula in (42) is a convex combination of these two.

Appendix C: Welfare and inequality aversion

In this appendix we establish that (25) is the welfare criterion developed by Atkinson (1970) with a degree to societal aversion to inequality equal to 2. We also apply the alternative criterion proposed by Sen (1976) to our framework. Let the utility enjoyed by the unemployed be denoted by $b\omega$, where $b \in [0, 1)$ is a parameter; an interpretation is that b is unemployment benefit, expressed as a fraction of the average wage. In our model, b is set to zero.

Appendix D establishes the symmetry between societal aversion to inequality and individual risk aversion.

Atkinson (1970)

The first welfare criterion that we use to compare a counterfactual situation with the current allocation is due to Atkinson (1970) and is extended by Fleurbaey and Hammond (2004). Atkinson's social welfare function can be written as a generalized average of individual utility:

$$\mathbb{W}(\eta) \equiv \left[\sum_{k=1}^{K} s_k \ell_k \omega_k^{1-\eta} + (b\omega)^{1-\eta} u \right]^{\frac{1}{1-\eta}}, \tag{43}$$

where $\eta \in \mathbb{R}$ is the *relative rate of inequality aversion*; $\eta = 0$ for Bentham and $\eta = +\infty$ for Rawls.[39] Using the no-arbitrage condition (12), we can rewrite (43) as

$$\mathbb{W}(\eta) = \omega \left(\bar{\ell}^{\eta} + u b^{1-\eta} \right)^{\frac{1}{1-\eta}},$$

where $\bar{\ell} \equiv \left(\sum_k s_k \ell_k^{\eta} \right)^{1/\eta}$ is an *inequality-adjusted* average employment rate ($\bar{\ell}^{\eta} < \ell$ iff $\eta > 0$).[40]

We henceforth let $b \to 0$ as in the main text. If $\eta = 0$ (Bentham) then $\mathbb{W} = \omega$, namely, society cares only about the average utility. Conversely, if $\eta \to +\infty$ (Rawls) then maximizing $\mathbb{W}$ requires minimizing the number of low income earners, i.e., minimizing u. In general, the welfare criterion in (43) balances average real wages with (un)employment concerns and the higher η, the higher the weight

[39] $\eta > 0$ and $\eta < 0$ correspond to inequality-adverse and inequality-seeking societal preferences, respectively. For $\eta = 1$, $\mathbb{W}$ is equal to $\exp\{\sum s_k \ell_k \ln \omega_k + u(\ln b + \ln \omega)\}$.

[40] In effect, it puts a heavier weight on sectors with a low employment rate than on sectors with a high employment rate relative to the standard arithmetic average.

on unemployment relative to real wages. For practical purposes, we use a degree of inequality aversion, $\eta = 2$, in between these two extremes, which yields

$$\frac{\mathbb{W}'}{\mathbb{W}} - 1 \approx \frac{\omega'}{\omega} - \frac{u'}{u} \tag{44}$$

as in (25). We pick this particular value for η because it has empirical support and yields a simple analytic expression. Stern (1977) finds $\eta = 1.97$ for the UK in the fiscal year 1973/4. The value $\eta = 2$ is slightly above the range $[1.61 - 1.72]$ estimated by Young (1990) from the nominal and effective US tax schedule for years 1957, 1967, and 1977 (more recently, Antràs, de Gortari, and Itskhoki (2016) find an implied value of $\eta = 0.6$ in their calibration exercise for the US).

More generally, for any $\eta > 1$, (25) generalizes to

$$\frac{\mathbb{W}'}{\mathbb{W}} - 1 \approx \frac{\omega'}{\omega} - \frac{1}{\eta - 1}\frac{u'}{u}$$

The higher η, the higher the weight put on changes in the unemployment rate (relative to changes in real wages). By the same token, for any $\eta < 1$, (25) becomes

$$\frac{\mathbb{W}'}{\mathbb{W}} - 1 \approx \frac{\omega'}{\omega} + \frac{1}{1-\eta}\left(\frac{\bar{\ell}'}{\bar{\ell}}\right)^{\eta};$$

the higher η, the higher the weight put on changes in the (inequality adjusted) employment rate.

Sen (1976)

An alternative welfare criterion that we may use is put forth by Sen (1976). Let

$$\mathbb{W} = \omega(1 - \mathbb{G}), \tag{45}$$

where $\mathbb{G}$ is the Gini coefficient of earnings inequality. This criterion satisfies several desirable properties.[41] Like in (43), $\mathbb{W}$ is increasing in average real wages and decreasing in real wage dispersion. If $b = 0$ as in the main text then

$$\mathbb{G} = u + (1-u)\mathbb{G}_\ell,$$

where $\mathbb{G}_\ell$ is the Gini coefficient *within the category of employed workers*. It is equal to zero if all employed workers earn the same wage, in which case the Gini coefficient $\mathbb{G}$ is simply the unemployment rate u. Plugging the expression above into (45) and computing welfare changes yields

$$\frac{\mathbb{W}'}{\mathbb{W}} - 1 = \frac{\omega'}{\omega} + \frac{\ell'}{\ell} + \frac{1 - \mathbb{G}'_\ell}{1 - \mathbb{G}_\ell} - 3, \tag{46}$$

[41] In addition to some standard axioms such as Complete Ordering, Convex Preferences, or Strict Monotonicity, this criterion satisfies the 'Rank Order Weighting' axiom whereby the weight of the richest person in the social welfare function is $1/n$ of the weight given to the n^{th} richest person. In general, using this criterion to compare allocations under different vectors of prices is problematic (as with all social welfare functions). In our case, the marginal utility of income is constant and the ranking in the population follows the the ranking of the μ_k's, which are time invariant.

where $\ell' \equiv 1 - u'$ is the counterfactual employment rate. The first term in the right-hand side above is the average real wage change; the second term accounts for changes in employed-unemployed inequality; the final term accounts for changes in within-employed inequality. The latter two effects are lumped together in Atkinson's criterion. For $\eta > 1$, across group inequality dominates within group inequality in an extreme way at the limit $b = 0$, which is why the within component seemingly drops out of (25).

Another way to emphasize the similarity between Sen and Atkinson's criteria is to consider the special case $u = \ell = 1/2$ and $\mathbb{G}'_\ell = \mathbb{G}_\ell$. In this case, (46) and (25) yield equivalent assessment of welfare changes. When u is lower than $1/2$, as is the case empirically (see column 1 of Table 4), Atkinson's criterion in (25) puts a higher weight on unemployment changes than does Sen's criterion in (46).

In the text, we have chosen to report only one – arguably standard – value for welfare changes in order to keep the analysis focused. Yet, our choice of Atkinson's over Sen's criterion is arguably somewhat arbitrary. For illustrative purposes, we plot in Figure 5 the comparison between Atkinson's and Sen's welfare criteria obtained under the TTIP scenario. Juxtaposing this graph to Figure 4, it becomes evident that Atkinson's welfare criterion is driven by changes in unemployment, whereas Sen's welfare criterion by changes in real wages.

Appendix D: Risk aversion

In this appendix we work out the case with risk-averse workers. Specifically, assume that the representative consumer has constant relative risk aversion preferences such that the level of utility $\tilde{\mathbb{U}}_i$ is defined as

$$\tilde{\mathbb{U}}_i \equiv \frac{\mathbb{U}_i^{1-a}}{1-a}$$

if $a \neq 1$ and $\tilde{\mathbb{U}}_i = \ln \mathbb{U}_i$ otherwise; $a > 0$ is the constant rate of relative risk aversion and $\mathbb{U}_i$ is defined in (2). This expression extends to the case of risk neutrality, $a = 0$, dealt with in the main text. Much of the analysis goes through unaltered; in what follows, we stress the main differences.

The first modification arises in subsection 4.1. We reset the definition of μ_{ik} in (9) as

$$\mu_{ik} \equiv \left(\frac{\tilde{\mu}_{ik}}{\nu_{ik}^{1-\lambda}} \right)^{\frac{1-a}{1-a\lambda}}.$$

We next replace the ex-ante free-mobility across sector (12) in subsection 4.3 by

$$\ell_{ik} w_{ik}^{1-a} = w_i^{1-a},$$

some $w_i > 0$. This expected wage is the certainty-equivalent level of earnings. In turn, the *certainty-equivalent real wage* in (13) now becomes

$$\forall k: \qquad \omega_i \equiv \frac{w_i}{\mathbb{P}_i} = \left(\frac{\ell_{ik}}{\mu_{ik}} \right)^{\frac{1}{1-\Lambda}}, \quad \text{where} \quad \Lambda \equiv 1 - \frac{(1-\lambda)(1-a)}{1-a\lambda}$$

collects parameters such that $\Lambda = \lambda$ if $a = 0$.

Turn next to subsections 5.2 and 5.3. The equilibrium employment rate in (22) becomes

$$\ell_i = \omega_i^{1-\Lambda} \bar{\mu}_i,$$

where the weights in $\bar{\mu}_i$ are labor shares.[42] It turn, we may replace (24) by

$$\frac{\ell_i'}{\ell_i} = \left(\frac{\omega_i'}{\omega_i}\right)^{1-\Lambda} \left[1 - \frac{\text{Cov}\left(s_{ik} - s_{ik}', \mu_{ik}\right)}{\bar{\mu}_i}\right].$$

Finally, turn to subsection 5.4 and Appendix C. We henceforth drop country subscripts i to ease comparison with the expressions in Appendix C and let $a \in (0, 1]$ to avoid a typology of uninteresting cases. The Atkinson welfare criterion in (43) may generalize as

$$\mathbb{W}(\eta) = \left[\sum_{k=1}^{K} s_k \ell_k \omega_k^{(1-\eta)(1-a)} + (b\omega)^{(1-\eta)(1-a)} u\right]^{\frac{1}{1-\eta}},$$

where $\eta \in \mathbb{R}$ is the relative rate of inequality aversion and $b \in [0, 1)$ is a parameter set to zero in our model.

Plugging the modified no-arbitrage condition $\ell_k w_k^{1-a} = w^{1-a}$ into this expression and using the definition of ω yield

$$\mathbb{W}(\eta) = \omega^{1-a} \left[\bar{\ell}^{\eta} + u b^{(1-\eta)(1-a)}\right]^{\frac{1}{1-\eta}}, \tag{47}$$

where $\bar{\ell} \equiv (\sum_k s_k \ell_k^{\eta})^{1/\eta}$ is the inequality-adjusted average employment rate defined in Appendix C.

It is important to note that η is the degree of societal aversion to inequality that comes on top of individual aversion to inequality; put differently, if the only motive for aversion to inequality is individual risk aversion, then η is equal to zero and parameter $a > 0$ already takes care of it. In order to understand this distinction further, consider the case $\eta = b = 0$, in which case (47) simplifies to $\mathbb{W} = \omega^{1-a}$. That is to say, if society is neutral to inequality but individuals are risk-averse, welfare is equal to a monotonic transformation of the certainty-equivalent real wage. In this case, maximizing $\mathbb{W}$ is equivalent to maximizing ω.

In the main text and in Appendix C, we consider the case $\eta = 2$. For any $\eta > 1$, (25) and (47) become

$$\frac{\mathbb{W}'}{\mathbb{W}} - 1 \approx (1-a)\frac{\omega'}{\omega} - \frac{1}{\eta - 1}\frac{u'}{u}.$$

Thus, the higher the degrees of risk and inequality aversion (the higher a and η), the higher the relative weight this criterion puts on unemployment relative to average earnings. Note also that a and η enter this expression symmetrically: the definition of the iso-welfare line is $(1-a)(1-\eta)(\omega'/\omega) = u'/u$.

The Sen criterion of Appendix C can be modified in a similar fashion.

[42] In the presence of risk aversion, labor shares differ from production shares. Let $s_{ik} \equiv L_{ik}/L_i$ define the labor share and $s_{ik}^E \equiv E_{ik}/E_i$ define production shares as before; the two are related by $s_{ik} = \kappa_i s_{ik}^E \mu_{ik}^{a/(1-a)}$, where κ_i collects parameters and i-wide variables.

Appendix E: Gravity estimation results

Table 7 reports the results of our gravity regressions. The estimated coefficients are in line with those of the literature (Head and Mayer 2014).

Appendix F: Methodology for counterfactual exercises

This Appendix provides the methodology for the three counterfactual exercises (TTIP, TPP, and TB) reported in Section 7. Under each scenario, we compute the counterfactual wages, prices, and vectors of shares of workers allocated to each sector in each country (w'_i, $\mathbb{P}'_i$, and $\{s'_{ik}\}_k$, respectively) *taking account of general equilibrium effects.* This implies in particular that we allow the vector of exporter-sector unobservables obtained in the gravity regression, $\hat{\kappa}_{ik}$, to change endogenously within each policy experiment. We perform our calculations by iteration using Matlab.

Counterfactual values under FTA scenarios (TTIP and TPP)

Let $\hat{x}$ define the estimate of any variable x obtained under the gravity regression in section 6.4. With the estimates $\hat{\delta}_x$, $\hat{\theta}$, and $\hat{\kappa}_{ik}$ at hand, we proceed to estimate counterfactual FTA bilateral trade flows relative to the current equilibrium (E'_{ijk}/E_{ijk}) for a set of 116 countries for which sufficient data is available. To this end we further need (i) the counterfactual trade costs, (ii) estimates of countrywide expenditures, E_j, (iii) estimates of the counterfactual countrywide expenditures, E'_j, and (iv) exporter-sector unobservables, κ'_{ik}'s, which we obtain as follows:

(i) Counterfactual trade costs under the FTA are set such that

$$\text{tariff}'_{ijk} = \begin{cases} 0 & \text{if} \quad i, j \quad \text{are members of the same FTA} \\ t_{ijk} & \quad\quad\quad \text{otherwise} \end{cases}$$

and we set the RTA dummy to one among FTA members.

(ii) Trade balances in general equilibrium so we calibrate the vector of country-level production values, E_i, to minimize the sum of squares of the excess demands,

$$ED_i \equiv \sum_{j=1}^{J} \sum_{k=1}^{K} \left(\frac{\hat{t}_{ijk}}{\hat{T}_{jk}} \right)^{-\hat{\theta}} \alpha_k E_j - E_i, \tag{48}$$

where $\hat{t}_{ijk} = \hat{\tau}_{ijk} \hat{\kappa}_{ik}$ and $\hat{T}_{jk} = (\sum_{i'} \hat{t}_{i'jk}^{-\hat{\theta}})^{-1/\hat{\theta}}$ by (20). Let $\mathbb{K}_N$ denote the set of non-tradable goods and services and $\mathbb{K}_T$ denote the complementary set of tradables. For all $k \in \mathbb{K}_N$ we impose $t_{jjk}/T_{jk} = 1$ for all j and $t_{ijk}/T_{jk} = +\infty$ for all $i \neq j$. Consumption shares α_k are calculated as sectoral production shares for the entire OECD region, using sector-level production data from the OECD Stan database. We use calibrated rather than actual values for E because we run our counterfactual exercise under the assumption that the macroeconomic sources of trade imbalances remain constant. We calibrate the vector $\mathbf{E} \equiv \begin{bmatrix} E_1 & \ldots & E_I \end{bmatrix}'$ so as to minimize the following sum of squares: $\mathbf{E^C} = \arg\min \sum_i (ED_i/E_i)^2$, where the 'C' superscript stands for 'calibrated'.[43] As a validation of this procedure, we compare the estimated vector of $\mathbf{E_i^C}$ to the actual GDP values in 2008 as reported by IMF. The correlation is 0.655 between $\mathbf{E_i^C}$ and nominal GDP (116 countries), and 0.94 between $\mathbf{E_i^C}$ and the nominal GDP corrected for trade imbalances (105 countries).

(iii) Trade balances in the FTA equilibrium if

$$ED_i' \equiv \sum_{j=1}^{J} \sum_{k=1}^{K} \left(\frac{t_{ijk}'}{T_{jk}'} \right)^{-\theta} \alpha_k E_j' - E_i' \tag{49}$$

is equal to zero, all i.

Let $\tilde{x} \equiv x'/x$ define the ratio of the counterfactual and actual values of any variable x. Here is how we compute the variables labelled with the superscript FTA in the expression above. First, we assume that the sources of macroeconomic imbalances are constant so that $\tilde{E}_j = \tilde{E}_j^C$, namely, counterfactual changes of E are equiproportional to changes in E^C and $E_j' = \tilde{E}_j \times E_j^C$. Second, $t_{ijk}' = \hat{t}_{ijk}\tilde{\tau}_{ijk}\tilde{\kappa}_{ik}$ by (19) and (30). Using the latter, it turns out that the ratio $\tilde{\kappa}$ is origin-specific (more on this below) and so we write $t_{ijk}' = \hat{t}_{ijk}\tilde{\tau}_{ijk}\tilde{\kappa}_i$. Finally, the gravity variables other than the RTA_{ij} dummy are time-invariant; therefore,

$$\tilde{\tau}_{ijk} = \begin{cases} \frac{1}{1+\text{tariff}_{ijk}} e^{\hat{\delta}_{rta}} & \text{if} \quad i, j \in \{\text{FTA member}\} \\ 1 & \text{otherwise.} \end{cases} \tag{50}$$

Using these relationships, we rewrite (49) as

$$ED_i' \equiv \sum_{j=1}^{J} \sum_{k=1}^{K} \frac{\left(\hat{t}_{ijk}\tilde{\tau}_{ijk}\tilde{\kappa}_i\right)^{-\hat{\theta}}}{\sum_{i'} \left(\hat{t}_{i'jk}\tilde{\tau}_{i'jk}\tilde{\kappa}_{i'}\right)^{-\hat{\theta}}} \alpha_k E_j^C \tilde{E}_j - E_i^C \tilde{E}_i, \tag{51}$$

where the $\hat{t}_{ijk}$'s are the same as in (48) and the E_i^C's are the excess-demand minimizing E_i's of (48). The unknowns here are the I-dimensional vector $\tilde{\mathbf{E}}$ and the $\tilde{\kappa}$. So far we have twice as many unknowns as equations.

[43] We may rewrite (48) in matrix form as $\mathbf{ED} = (\mathbf{T} - \mathbf{I})\mathbf{E}$, where $\mathbf{ED}$ and $\mathbf{E}$ are the I-dimensional vectors stacking up the ED_i's and the E_i's, $\mathbf{I}$ is the identity matrix, and $\mathbf{T}$ is an $I \times I$ matrix, the typical element of which is equal to $\sum_k (t_{ijk}/T_{jk})^{-\theta}\alpha_k$. Generically, there exists no vector $\mathbf{E}$ that solves $\mathbf{ED} = \mathbf{0}$. Such a vector would be the eigenvector of $\mathbf{T}$ associated with the unit eigenvalue of $\mathbf{T}$ but, generically, the eigenvalues of $\mathbf{E}$ are different from one. Indeed, the eigenvalues of $\mathbf{T}$, denoted by $\psi \in \mathbb{C}$, are the solutions to the I-dimensional polynomial $\det(\mathbf{T} - \psi\mathbf{I}) = 0$ but $\psi = 1$ is not one of its roots in general.

(iv) Under the assumption that the technology parameters μ_{ik} and φ_{ik} are time invariant, the ratio $\tilde{\kappa}_j$ simplifies to $\tilde{\kappa}_j = \tilde{w}_j^{\lambda} \tilde{P}_j^{1-\lambda}$ by definition of κ_{jk} in (30). Income being proportional to wages in our Ricardian model, we obtain $\tilde{w}_i = \tilde{E}_i$ and thus

$$\tilde{\kappa}_i = \tilde{E}_i^{\lambda} \widetilde{\mathbb{P}}_i^{1-\lambda}.$$

In the trade equilibrium, the price index is equal to $\mathbb{P}_i = \gamma \prod_k \left[\sum_j (\tau_{jik}\kappa_{ik})^{-\theta}\right]^{-\alpha_k/\theta}$. Using the tilde notation for prices as well as (50), we may rewrite the expression above as $e\tilde{\kappa}_i = 0$, where the 'e' in $e\tilde{\kappa}_i$ stands for 'error' or 'excess' by analogy with ED_i in (49), and

$$e\tilde{\kappa}_i \equiv \tilde{E}_i^{\lambda} \widetilde{\mathbb{P}}_i^{1-\lambda} - \tilde{\kappa}_i = \tilde{E}_i^{\lambda} \prod_{k=1}^{K} \left[\frac{\sum_{j=1}^{J} \left(\hat{\tau}_{ijk}\hat{\kappa}_{jk}\tilde{\tau}_{ijk}\tilde{\kappa}_j\right)^{-\hat{\theta}}}{\sum_{j=1}^{J} \left(\hat{\tau}_{ijk}\hat{\kappa}_{jk}\right)^{-\hat{\theta}}} \right]^{-\frac{\alpha_k}{\hat{\theta}}(1-\lambda)} - \tilde{\kappa}_i, \tag{52}$$

where $\lambda = 0.6$ and $\tau_{ijk} = +\infty$ for all $k \in \mathbb{K}_N$ and $i \neq j$. The $2I$ unknowns of this system are the vectors $\tilde{\mathbf{E}}$ and $\tilde{\kappa}$.

We jointly estimate $\tilde{\mathbf{E}}$ and $\tilde{\kappa}$ by minimizing the sum of squares of ED_i'/E_i in (51) and of $e\tilde{\kappa}_i$ in (52). This being a high-dimensional non-linear system, we do this by iterations using Matlab.

We can now compute the general equilibrium effects on domestic flows and on the bilateral trade flows in tradable good sectors by using the counterfactual trade cost ratios from (50) and the estimated ratios $\tilde{\mathbf{E}}$ and $\tilde{\kappa}$:

$$\tilde{E}_{ijk} = \begin{cases} \tilde{\tau}_{ijk}^{-\hat{\theta}} \tilde{\kappa}_i^{-\hat{\theta}} \dfrac{\sum_{i'=1}^{I} \left[\hat{\tau}_{i'jk}\hat{\kappa}_{i'k}\right]^{-\hat{\theta}}}{\sum_{i'=1}^{I} \left[\hat{\tau}_{i'jk}\hat{\kappa}_{i'k}\tilde{\tau}_{i'jk}\tilde{\kappa}_{i'}\right]^{-\hat{\theta}}} \tilde{E}_j & \text{if} \quad k \in \mathbb{K}_T \\ \tilde{E}_i & \text{if} \quad k \in \mathbb{K}_N \quad \text{and} \quad j = i \\ 0 & \text{if} \quad k \in \mathbb{K}_N \quad \text{and} \quad j \neq i \end{cases} \tag{53}$$

The simplicity of this expression for $k \in \mathbb{K}_N$ arises because domestic production is linear in domestic income by virtue of homogeneous preferences.

The counterfactual FTA labor shares are equal to

$$s_{ik}' = \frac{\sum_{j=1}^{J} E_{ijk}\tilde{E}_{ijk}}{\sum_{k'=1}^{K}\sum_{j=1}^{J} E_{ijk'}\tilde{E}_{ijk'}}, \tag{54}$$

where the E_{ijk}'s denote actual trade and domestic flows.

The change in the employment rates under the new free-trade agreement equilibrium is now an interaction of both the expansion effect and the reallocation effect. It can be obtained as

$$\frac{\ell_i'}{\ell_i} = \left(\frac{\tilde{E}_i}{\widetilde{\mathbb{P}}_i}\right)^{1-\lambda} \frac{\sum_k s_{ik}'\mu_k}{\sum_k s_{ik}\mu_k}.$$

Counterfactual values under balanced trade (TB)

Our aim here is to estimate the unemployment and welfare effects of eliminating trade imbalances. The estimation procedure of previous subsection remains valid, with the exception that under the trade balance scenario all tariffs remain unchanged.

We use E_i to denote aggregate demand of country i and Y_i its output, and we define $b_i \equiv E_i/Y_i$. Thus $1 - b_i$ is i's trade balance (exports minus imports) as a share of output. Therefore, $b_i > 1$ holds in deficit countries and $b_i \in (0,1)$ holds in surplus countries. We may thus write the equivalent of (48) as

$$ED_i \equiv \sum_{j=1}^{J}\sum_{k=1}^{K}\left(\frac{\hat{t}_{ijk}}{\hat{T}_{jk}}\right)^{-\hat{\theta}}\alpha_k E_j - \frac{E_i}{b_i}.$$

We compute b_i from trade balance and GDP data. As in the previous subsection, we estimate the vector $\mathbf{E}^{TB}$ as $\mathbf{E}^{TB} = \arg\min \sum_i (ED_i/E_i)^2$.

Next, let us define $\tilde{x} \equiv x^{TB}/x$ as the ratio of the counterfactual to the actual values of any variable x, where now the counterfactual situation is one where trade imbalances are eliminated throughout the world. We thus set $b_i^{TB} = 1$, all i so that $\tilde{b}_i \equiv b_i^{TB}/b_i = 1/b_i$. Tariffs and all gravity variables are unchanged and hence $\tilde{\tau}_{ijk} = 1$ for all i, j, k. The excess demand system in this counterfactual world is isomorphic to (51):

$$ED_i^{TB} \equiv \sum_{j=1}^{J}\sum_{k=1}^{K}\frac{\left(\hat{t}_{ijk}\tilde{\kappa}_i\right)^{-\hat{\theta}}}{\sum_{i'}\left(\hat{t}_{i'jk}\tilde{\kappa}_{i'}\right)^{-\hat{\theta}}}\alpha_k E_j^{TB}\tilde{E}_j - E_i^{TB}\tilde{E}_i. \tag{55}$$

By the same token, the system of 'excess-$\tilde{\kappa}$' is equal to

$$e\tilde{\kappa}_i = \tilde{E}_i^{\lambda}\prod_{k=1}^{K}\left[\frac{\sum_{j=1}^{J}\left(\hat{\tau}_{ijk}\hat{\kappa}_{jk}\tilde{\kappa}_j\right)^{-\hat{\theta}}}{\sum_{j=1}^{J}\left(\hat{\tau}_{ijk}\hat{\kappa}_{jk}\right)^{-\hat{\theta}}}\right]^{-\frac{\alpha_k}{\hat{\theta}}(1-\lambda)} - \tilde{\kappa}_i. \tag{56}$$

We solve for the vectors $\mathbf{E}$ and $\tilde{\kappa}$ that jointly minimize the sums of squares in (55) and (56).

Finally, we compute the counterfactual (balanced trade) trade flows, labor shares, and the employment rates as in (53), (54), and

$$\frac{\ell_i^{TB}}{\ell_i} = \left(\frac{\tilde{E}_i}{\tilde{\mathbb{P}}_i}\right)^{1-\lambda}\frac{\sum_k s_{ik}^{TB}\mu_k}{\sum_k s_{ik}\mu_k}, \tag{57}$$

respectively.

Appendix G: Unemployment and welfare results for different values of λ

Table 8 reports unemployment and welfare results for our three different counterfactuals (TTIP, TPP and trade imbalance elimination) for values of the matching elasticity λ corresponding to the lower bound ($\lambda = 0.3$) and the upper bound ($\lambda = 0.9$) reported by Petrongolo and Pissarides (2001). The results for TTIP and TPP are quite insensitive to these alternative assumptions about the value of λ, both qualitatively and quantitatively. By contrast, unemployment and welfare figures switch signs for most countries in between these two extremes for the trade rebalancing experiment. This was to be expected because real wages are greatly affected in this policy experiment and different values of λ correspond to different weights put on ω in the computation of both u and $\mathbb{W}$. Two further features of the figures reported in table 8 are to be expected by inspection of (24). First, the lower the value of λ, the higher the negative correlation between unemployment and real wage changes. Second, the figures reported in the text belong to the intervals consisting of the figures in table 8. These thus provide bounds to the welfare and unemployment effects of our policy experiments.

References

[1] Aichele, Rahel, Gabriel Felbermayr and Inga Heiland, 2014. 'Going Deep: The Trade and Welfare Effects of TTIP, CESinfo Working Paper 5150.

[2] Antràs, Pol, Alonso de Gortari, and Oleg Itskhoki, 2016. 'Inequality, costly redistribution and welfare in an open economy.' In progress, Harvard and Princeton.

[3] Alvarez, Fernando and Robert Jr. Lucas, 2007. 'General equilibrium analysis of the Eaton-Kortum model of international trade,' Journal of Monetary Economics 54(6), 1726-1768.

[4] Arkolakis, Costas, Arnaud Costinot, and Andres Rodríguez-Clare, 2012. 'New Trade Models, Same Old Gains?' American Economic Review 102(1), 94-130.

[5] Arkolakis, Costas and Federico Esposito, 2015. 'Endogenous labor supply and the gains from international trade.' Processed, Yale University.

[6] Armington, Paul, 1969. 'A Theory of Demand for Products Distinguished by Place of Production,' International Monetary Fund Staff Papers 16, 159-78.

[7] Artuç, Erhan, Shubham Chaudhuri, and John McLaren. 2010. 'Trade Shocks and Labor Adjustment: A Structural Empirical Approach.' American Economic Review, 100(3): 1008-45.

[8] Atkeson, Andrew, and Ariel T. Burstein, 2010. 'Innovation, Firm Dynamics, and International Trade,' Journal of Political Economy 118(3), 433-484.

[9] Atkinson, Anthony, 1970. 'On the measurement of inequality.' Journal of Economic Theory 2, 244-263.

[10] Barnichon, Regis and Andrew Figura, 2015. 'Labor Market Heterogeneity and the Aggregate Matching Function.' American Economic Journal: Macroeconomics, 7(4): 222-249.

[11] Bertelsmann Report (2013). 'Transatlantic Trade and Investment Partnership (TTIP): Who benefits from a free trade deal?' Bertelsmann Stiftung.

[12] Brecher, Richard, 1974. 'Minimum Wage Rates and the Pure Theory of International Trade.' Quarterly Journal of Economics 88, 98-116.

[13] Burstein, Ariel, and Jonathan Vogel, 2015. 'International trade, technology, and the skill premium.' Manuscript, UCLA and Columbia.

[14] Carrère, Céline, Marco Fugazza, Marcelo Olarreaga, and Frédéric Robert-Nicoud, 2014. 'Trade in Unemployment,' CEPR Discussion Paper 9916.

[15] Chor, Davin, 2010. 'Unpacking sources of comparative advantage: A quantitative approach,' Journal of International Economics 82(2), 152-167.

[16] Coşar, A. Kerem, Nezih Guner, and James Tybout, 2016. 'Firm Dynamics, Job Turnover, and Wage Distributions in an Open Economy,' American Economic Review, 106(3), 625-663.

[17] Costinot, Arnaud, 2009. 'Jobs, Jobs, Jobs: A 'New' Perspective on Protectionism.' Journal of the European Economic Association 7(5), 1011-1041.

[18] Costinot, Arnaud, Dave Donaldson and Ivana Komunjer, 2012. "What Goods Do Countries Trade? A Quantitative Exploration of Ricardo's Ideas." Review of Economic Studies, 79, 581-608.

[19] Costinot, Arnaud, and Andrés Rodríguez-Clare, 2014. 'Trade theory with numbers: Quantifying the consequences of globalization.' In Gopinath, Helpman, and Rogoff (eds), Handbook of International Economics Vol. IV, 197-261, Elsevier.

[20] Cuñat, Alejandro and Marc J. Melitz, 2012. 'Volatility, Labor Market Flexibility, and the Pattern of Comparative Advantage,' Journal of the European Economic Association, 225-254.

[21] Davidson, Carl, Lawrence Martin and Stephen Matusz, 1988. 'The Structure of Simple General Equilibrium Models With Frictional Unemployment,' Journal of Political Economy, 96, 1267-1293.

[22] Davidson, Carl, Lawrence Martin and Stephen Matusz, 1999. 'Trade and Search Generated Unemployment.' Journal of International Economics 48(2), 271-99.

[23] Davis, Donald, 1998. 'Does European Unemployment Prop Up American Wages? National Labor Markets and Global Trade.' American Economic Review 88, 478-494.

[24] Davis, Donald R. and James Harrigan, 2011. 'Good jobs, bad jobs, and trade liberalization,' Journal of International Economics 84(1), 26-36.

[25] Dekle, Robert, Jonathan Eaton and Samuel Kortum. 2007. 'Unbalanced trade.' American Economic Review 97(2), 351-355.

[26] Dix-Carneiro, Rafael, 2014. 'Trade Liberalization and labour market dynamics.' Econometrica, 82, 825-885.

[27] Eaton, Jonathan, and Samuel Kortum, 2002. "Technology, geography, and trade." Econometrica 70(5), 1741-1780.

[28] Eaton, Jonathan, Samuel Kortum and Brent Neiman, 2013. 'On Deficits and Unemployment.' Revue Economique 64(3), 405-420.

[29] Edmond, Chris, Virgiliu Midrigan, and Daniel Yi Xu, 2015. 'Competition, markups, and the gains from international trade.' American Economic Review 105(10), 3183-3221.

[30] Egger, Peter, Joseph Francois, Miriam Manchin, and Douglas Nelson, 2015. 'Non-tariff barriers, integration and the transatlantic economy.' Economic Policy 30(83), 539-584.

[31] Egger, Hartmut, and Udo Kreickemeier, 2012. 'Fairness, trade, and inequality,' Journal of International Economics 86(2), 184-196.

[32] Epifani, Paolo, and Gino Gancia, 2007. 'Openness, government size and the terms of trade.' Review of Economic Studies 76(2), 629-668.

[33] Faber, Ben and Thibault Fally, 2015. 'Firm heterogeneity in consumption baskets: Evidence from home and store scanner data. Mimeo, UC Berkeley.

[34] Fajgelbaum, Pablo, 2013. 'Labor Market Frictions, Firm Growth, and International Trade.' NBER Working Paper 19492.

[35] Felbermayr, Gabriel, Benedikt Heid, Mario Larch, and Erdal Yalcin, 2015. 'Macroeconomic potentials of transatlantic free trade: A high resolution perspective for Europe and the world,' Economic Policy 30(83), 491-537.

[36] Felbermayr, Gabriel, Julien Prat and Hans-Jörg Schmerer, 2011. 'Globalization and labor market outcomes: Wage bargaining, search frictions, and firm heterogeneity,' Journal of Economic Theory 146(1), 39-73.

[37] Fleurbaey, Marc, and Peter J. Hammond, 2004. 'Interpersonal comparable utility.' In Barbera, Hammond, and Seidl (eds), Handbook of Utility Theory Vol. II (Extensions), Springer.

[38] Fontagné, Lionel, Julien Gourdon and Sébastien Jean, 2013. 'Transatlantic Trade: Whither Partnership, Which Economic Consequences? CEPII Policy Brief, CEPII, Paris.

[39] Francois, Joseph, Miriam Manchin, Hanna Norberg, Olga Pindyuk and Patrick Tomberger, 2013. 'Reducing Transatlantic Barriers to Trade and Investment An Economic Assessment'. CEPR Report.

[40] Galle, Simon, Andrés Rodríguez-Clare, and Moises Yi, 2015. 'Slicing the pie: Quantifying the aggregate and distributional effects of trade.' In progress, UC Berkeley.

[41] Goldberg, Pinelopi Koujianou and Nina Pavcnik, 2007. 'Distributional Effects of Globalization in Developing Countries.' Journal of Economic Literature 45(1), 39-82.

[42] Head, Keith, and Thierry Mayer, 2013, 'What separates us? Sources of resistance to globalization.' Canadian Journal of Economics, 46(4), 1196-1231.

[43] Head, Keith, and Thierry Mayer, 2014. 'Gravity Equations: Workhorse, Toolkit, and Cookbook.' In Gopinath, Helpman, and Rogoff (eds), Handbook of International Economics Vol. IV, 131-195, Elsevier.

[44] Head, Keith, Thierry Mayer, and Mathias Thoenig, 2014. 'Welfare and trade without Pareto,' American Economic Review 104(5), 310-316.

[45] Heid, Benedikt, and Mario Larch, 2016. 'Gravity with unemployment,' Journal of International Economics, forthcoming.

[46] Helpman, Elhanan, and Oleg Itskhoki, 2010. "Labor Market Rigidities, Trade and Unemployment." Review of Economic Studies 77, 1100-1137.

[47] Helpman, Elhanan, Oleg Itskhoki and Stephen Redding, 2010. 'Inequality and Unemployment in a Global Economy,' Econometrica 78(4), 1239-1283.

[48] Helpman, Elhanan, Oleg Itskhoki and Stephen Redding, 2013. 'Trade and Labor Market Outcomes,' Advances in Economics and Econometrics, Tenth World Congress of the Econometric Society, Volume 2: Applied Economics, Daron Acemoglu, Manuel Arellano and Eddie Dekel, editors, Cambridge University Press.

[49] Helpman, Elhanan, Oleg Itskhoki, Marc-Andreas Muendler, and Stephen Redding, 2015. 'Trade and inequality: From theory to estimation.' NBER Working Paper 18008 (revised).

[50] Krishna, Pravin, Jennifer P. Poole, and Mine Zeynep Senses, 2012. 'Trade, labor market frictions, and residual wage inequality across worker groups,' American Economic Review 102(3): 417–423.

[51] Krugman, Paul R., 1993. 'What Do Undergrads Need To Know About Trade' American Economic Review Papers and Proceedings 83(2): 23-26.

[52] Kemp, Murray C., 1962. 'The gains from international trade.' Economic Journal 72, 803-819.

[53] Kreickemeier, Udo and Douglas Nelson, 2006. 'Fair wages, unemployment and technological change in a global economy,' Journal of International Economics 70(2), 451-469.

[54] Levinsohn, James, 1999. 'Employment responses to international liberalization in Chile.' Journal of International Economics 47(2), 321-344.

[55] Lü, Xiaobo, Kenneth Scheve, and Matthew J. Slaughter, 2012. 'Inequity aversion and the international distribution of trade protection.' American Journal of Political Science 56(3), 638-655.

[56] McCaig, Brian and Nina Pavcnik, 2012. 'Export Markets and Labor Reallocation In a Poor Country.' NBER Working paper 22045.

[57] Melitz, Mark and Steve J. Redding, 2015. 'New Trade Models, New Welfare Implications,' American Economic Review 105(3), 1105-1146.

[58] Menezes-Filho, Naércio Aquino, and Marc-Andreas Muendler, 2011. 'Labor Reallocation in Response to Trade Reform.' NBER Working Papers 17372.

[59] Nunn, Nathan, and Daniel Trefler, 2014. 'Domestic institutions as a source of comparative advantage.' In Gopinath, Helpman, and Rogoff (eds), Handbook of International Economics Vol. IV, 131-195, Elsevier.

[60] Ossa, Ralph, 2015. 'Why trade matters after all,' Journal of International Economics 97(2): 266-277.

[61] Petri, Peter A., Michael G. Plummer and Fan Zhai, 2012. 'The Trans-Pacific Partnership and Asia-Pacific Integration: A Quantitative Assessment.' Policy Analyses in International Economics, Peterson Institute for International Economics.

[62] Petrongolo, Barbara and Christopher A. Pissarides, 2001. 'Looking into the Black Box: A Survey of the Matching Function.' Journal of Economic Literature 39, 390–431.

[63] Revenga, Ana, 1992. 'Exporting Jobs?: The Impact of Import Competition on Employment and Wages in U.S. Manufacturing.' The Quarterly Journal of Economics 107(1), 255-284.

[64] Rodrik, Dani, 1998. 'Why Do More Open Economies Have Bigger Governments?' Journal of Political Economy 106(5), 997-1032.

[65] Samuelson, Paul, 1952. 'The transfer problem and transport costs: the terms of trade when impediments are absent.' Economic Journal 62, 278-304.

[66] Samuelson, Paul A., 1962. 'The gains from international trade once again.' Economic Journal 72, 820-829.

[67] Sen, Amartya, 1976. 'Real national income.' Review of Economic Studies 43(1), 19-39.

[68] Simonovska, Ina and Michael E. Waugh, 2014. 'The elasticity of trade: Estimates and evidence.' Journal of International Economics 92(1), 34-50.

[69] Stern, N., 1977. 'The marginal valuation of income.' In: Artis and Nobay (eds) Essays in Economic Analysis, University Press, Cambridge.

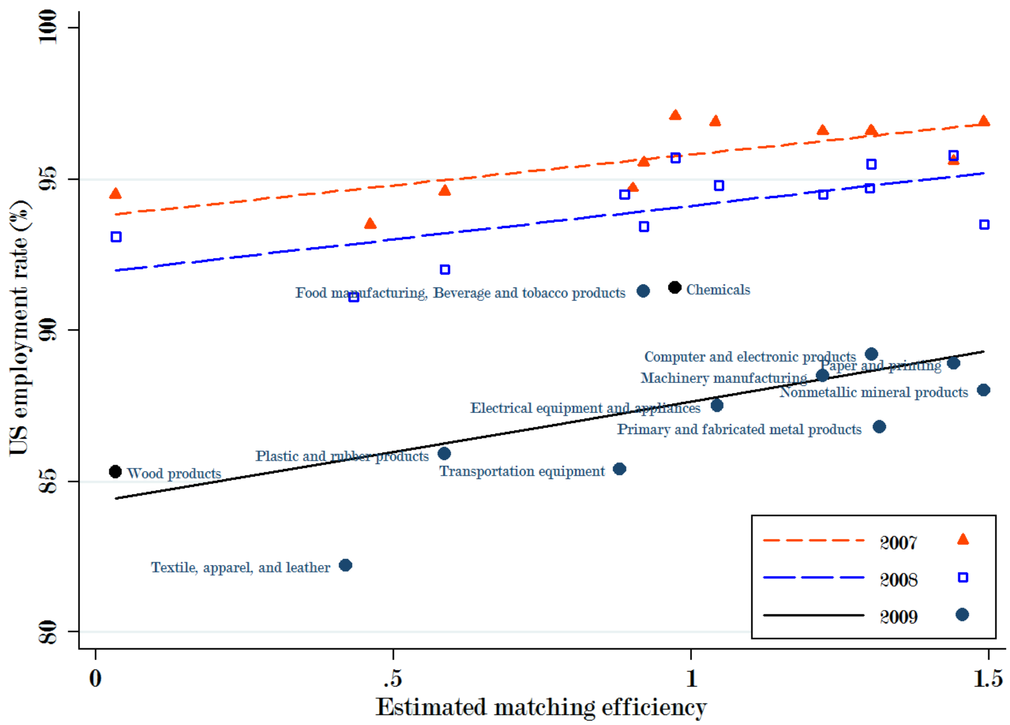
[70] Trefler, Daniel, 2004. 'The Long and Short of the Canada-U.S. Free Trade Agreement.' American Economic Review 94, 870-895.

[71] Verhoogen, Eric A. (2008). 'Trade, quality upgrading, and wage inequality in the mexican manufacturing sector. Quarterly Journal of Economics 123 (2), 489-530.

[72] Young, H.P., 1990. 'Progressive taxation and equal sacrifice.' American Economic Review 80, 253–266.

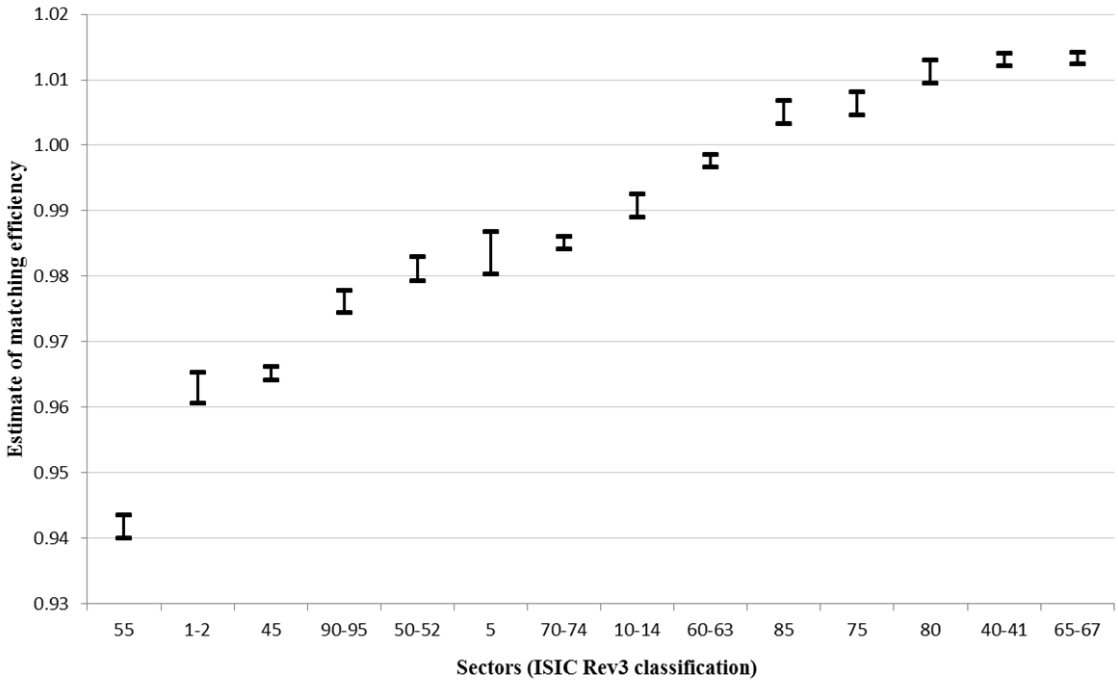
Figures

Figure 1: Correlation between the estimated μ_m's and the US employment rates for 12 BLS manufacturing sectors



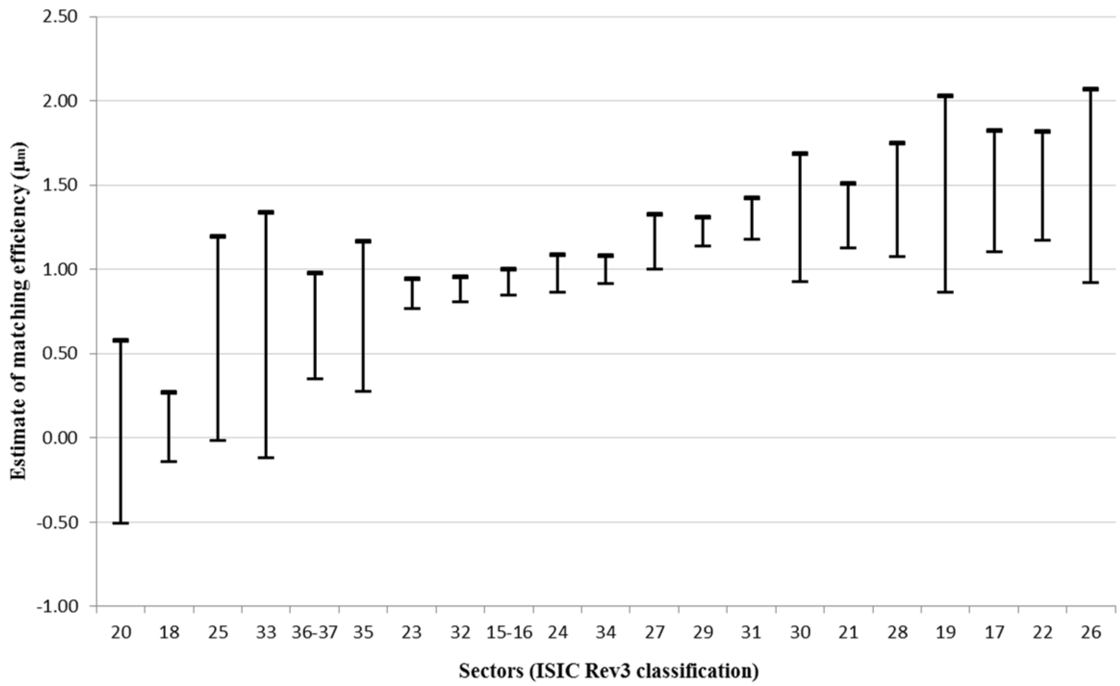
Note: The figure plots the linear fit between matching efficiencies estimated for our OECD-25 sample of countries on 2001-2008 and the US sectoral employment data (sourced from the US Bureau of Labor Statistics) for 12 manufacturing sectors for which sector-specific employment data was available, for years 2007-2009.
Source: BLS and authors' calculations.

Figure 2: Estimated sector-specific labor market matching efficiencies with 90%-confidence intervals, for 14 aggregate sectors with available unemployment rate data (excluding manufacturing sector).



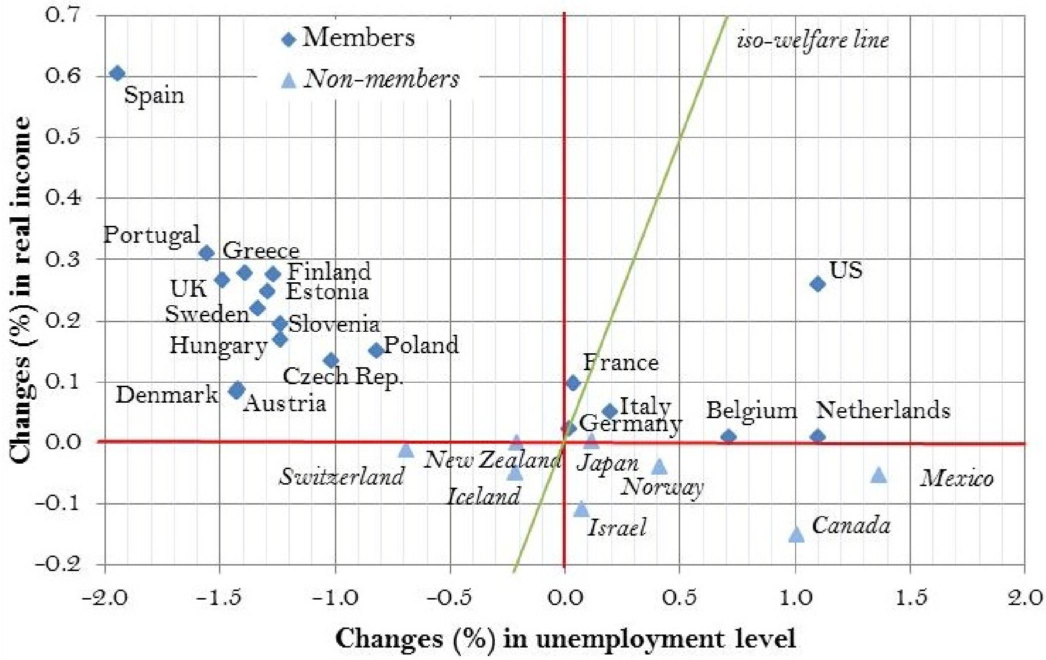
Source: Authors' calculations.

Figure 3: Estimated sector-specific labor market matching efficiencies (μ_m's) with 90%-confidence intervals, for 21 disaggregated manufacturing sectors.



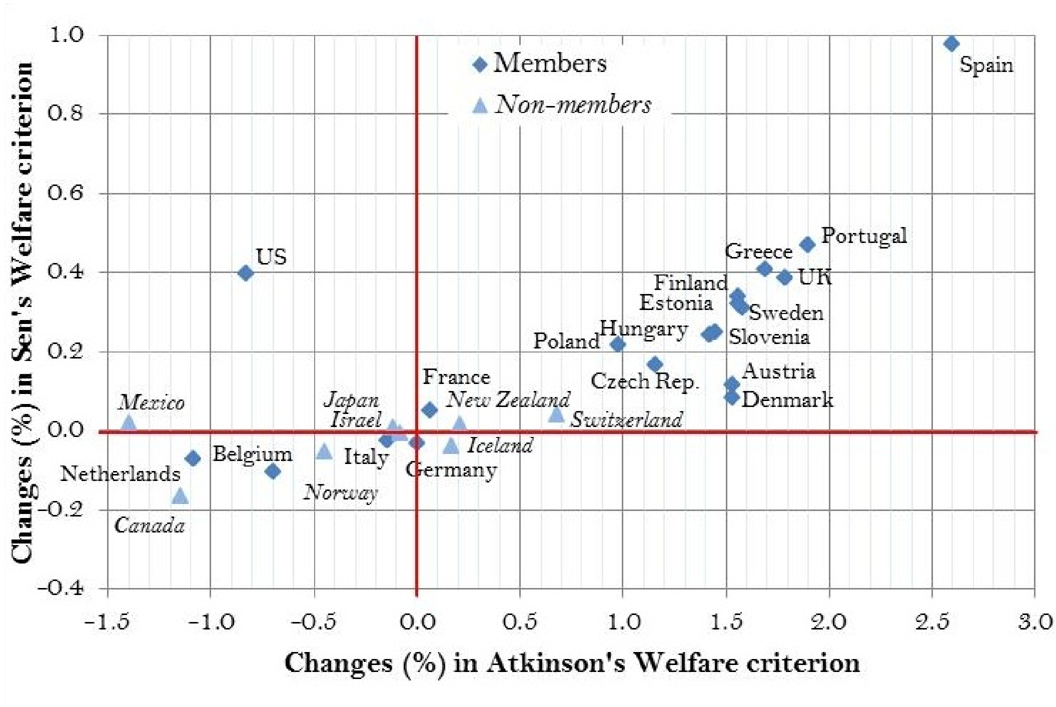
Source: Authors' calculations.

Figure 4: Relative changes in unemployment levels and real income for members and non-members of TTIP



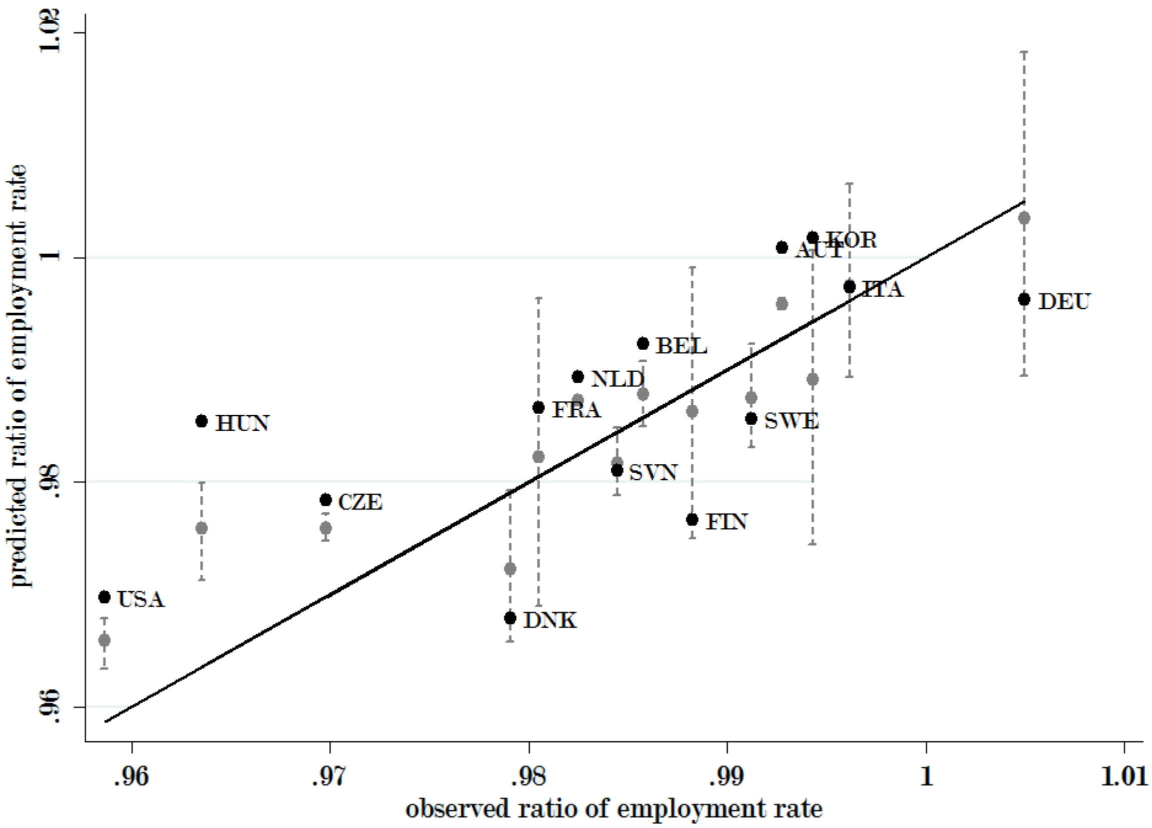
Note: Figure based on the results in Table 4. The *'iso-welfare'* line splits the sample into welfare-gaining countries (above the line) and welfare-losing countries (below the line).
Source: Authors' calculations.

Figure 5: Relative welfare changes under the TTIP scenario according to Sen's and Atkinson's criteria



Source: Authors' calculations.

Figure 6: Out-of-sample prediction for national employment rates in 2011



Note: The figure plots the observed ratios of 2011-to-2008 national employment rates (horizontal axis) against the ratios predicted using (28) (vertical axis). Black dots report predicted ratios based on the expansion effect only. The expansion effect affects all sectors proportionally and is approximated by the median ratio of all sectoral employment rates for each country. Grey dots report the overall predicted ratios in country-level employment rates obtained by combining both the expansion and the reallocation effects as per (28); the reallocation effect is computed using our values of sectoral matching efficiencies estimated on a sample period 2001-2008 (see Table 2) and the actual production shares in relevant years. The figure also reports the 45° line and 90% confidence intervals for the overall predicted ratios of the employment rate.
Source: ILO and authors' calculations.

Tables

Table 1: Availability of ISICRev3 sector-specific unemployment data (KILM database)

15 aggregated sectors
(available unemployment rate data)

ISICRev3	**Sector description**
1-2	Agriculture, hunting and forestry
5	Fishing
10-14	Mining and quarrying
15-37	*Manufacturing*
40-41	Electricity, gas and water supply
45	Construction
50-52	Wholesale and retail trade - repairs
55	Hotels and restaurants
60-63	Transport, storage and communications
65-67	Financial intermediation
70-74	Real estate, renting and business activities
75	Public admin. and defence - social security
80	Education
85	Health and social work
90-95	Other community, social and personal services

21 disaggregated manufacturing sectors
(unavailable unemployment rate data)

ISICRev3	**Sector description**
15-16	Food, beverages and tabacco products
17	Textiles
18	Wearing apparel, dressing and dyeing of fur
19	Leather, leather products and footwear
20	Wood and products of wood and cork
21	Pulp, paper and paper products
22	Printing and publishing
23	Coke, refined petroleum products and nuclear fuel
24	Chemicals and chemical products
25	Rubber and plastics products
26	Other non-metallic mineral products
27	Basic metals
28	Fabricated metal products, except machinery and equip.
29	Machinery and equipment, n.e.c.
30	Office, accounting and computing machinery
31	Electrical machinery and apparatus, n.e.c.
32	Radio, television and communication equipment
33	Medical, precision and optical instruments
34	Motor vehicles, trailers and semi-trailers
35	Other transport equipment
36-37	Other miscellaneous manufacturing

Source: KILM and authors' presentation.

Table 2: Estimates of sector-specific labor market matching efficiencies, μ_{ik}

(1)	(2)	(3)	(4)	(5)
			Clustered	$\ell_{ik}/\ell_{ik'}$
ISICRev3	Sector description	μ_k	Std. Err.	(k' = Agricult.)
1-2	Agriculture, hunting and forestry	0.962	*0.0013*	1.000
5	Fishing	0.984	*0.0019*	1.022
10-14	Mining and quarrying	0.991	*0.0010*	1.029
15-16	Food, beverages and tabacco products	0.921	*0.0400*	0.957
17	Textiles	1.462	*0.1854*	1.519
18	Wearing apparel, dressing and dyeing of fur	0.062	*0.1066*	NS
19	Leather, leather products and footwear	1.442	*0.2986*	1.498
20	Wood and products of wood and cork	0.033	*0.2772*	NS
21	Pulp, paper and paper products	1.316	*0.0990*	1.367
22	Printing and publishing	1.490	*0.1659*	1.548
23	Coke, refined petroleum products and nuclear fuel	0.852	*0.0470*	0.885
24	Chemicals and chemical products	0.973	*0.0579*	1.011
25	Rubber and plastics products	0.587	*0.3103*	NS
26	Other non-metallic mineral products	1.492	*0.2952*	1.550
27	Basic metals	1.161	*0.0834*	1.206
28	Fabricated metal products, except machinery and equipment	1.409	*0.1728*	1.464
29	Machinery and equipment, n.e.c.	1.221	*0.0450*	1.269
30	Office, accounting and computing machinery	1.303	*0.1961*	1.354
31	Electrical machinery and apparatus, n.e.c.	1.299	*0.0653*	1.349
32	Radio, television and communication equipment	0.877	*0.0397*	0.911
33	Medical, precision and optical instruments	0.606	*0.3735*	NS
34	Motor vehicles, trailers and semi-trailers	0.995	*0.0438*	1.034
35	Other transport equipment	0.719	*0.2279*	0.747
36-37	Other miscellaneous manufacturing	0.662	*0.1625*	0.688
40-41	Electricity, gas and water supply	1.013	*0.0005*	1.053
45	Construction	0.965	*0.0006*	1.003
50-52	Wholesale and retail trade - repairs	0.981	*0.0010*	1.019
55	Hotels and restaurants	0.942	*0.0010*	0.978
60-63	Transport, storage and communications	0.998	*0.0006*	1.037
65-67	Financial intermediation	1.013	*0.0006*	1.053
70-74	Real estate, renting and business activities	0.985	*0.0005*	1.023
75	Public admin. and defence - compulsory social security	1.006	*0.0010*	1.046
80	Education	1.011	*0.0010*	1.051
85	Health and social work	1.005	*0.0011*	1.044
90-95	Other community, social and personal services	0.976	*0.0010*	1.014

Note: The table displays estimates of matching efficiencies for 35 sectors classified according to ISICRev3 (adjusted $R^2 = 0.6$). Columns 1 and 2 report the ISICRev3 classification code and sector description, and columns 3 and 4 report the coefficient estimates and the clustered (product) standard errors, respectively. Estimates are obtained using non-linear least squares on a sample of 25 OECD countries for the period 2001-2008 (1,624 observations). Column 5 reports the relative employment rates of each sector relative to the 'Agriculture, hunting, and forestry' sector of reference. By (13) the relative employment rate between any two sectors is given by the relative matching efficiencies, $\ell_{ik}/\ell_{ik'} = \mu_k/\mu_{k'}$, and this must hold for any country i. This ratio is not calculated for estimates not significant at 10%, which we signal with 'NS' in the fifth column.

Source: Authors' calculations.

Table 3: Correlation between estimated matching efficiencies and US sectoral employment rates for the disaggregated manufacturing sectors

	Correlation	Spearman correlation
2005	0.676	0.634
2006	0.648	0.595
2007	0.741	0.709
2008	0.659	0.666
2009	0.558	0.538

Note: The table displays the correlation and the Spearman correlation between matching efficiencies estimated for our OECD-25 sample of countries and the US sectoral employment data (sourced from the US Bureau of Labor Statistics) for 12 manufacturing sectors for which sector-specific employment data is available.
Source: BLS and authors' calculations.

Table 4: Changes in unemployment rate, real wage, and welfare under TTIP (in percent).

		(1) u_i^{2008}	(2) $\left(\frac{\sum_k s_{ik}^{TTIP}\mu_k}{\sum_k s_{ik}^{2008}\mu_k} - 1\right)$	(3) $\left(\frac{u_i^{TTIP}}{u_i^{2008}} - 1\right)$	(4) $\left(\frac{\omega^{TTIP}}{\omega^{2008}} - 1\right)$	(5) $\left(\frac{\mathbb{W}^{TTIP}}{\mathbb{W}^{2008}} - 1\right)$
TTIP	Austria	3.8	0.021	-1.421	0.087	1.509
members	Belgium	7.0	-0.057	0.713	0.010	-0.704
	Czech Rep.	4.4	-0.007	-1.014	0.133	1.147
	Denmark	3.4	0.017	-1.430	0.082	1.512
	Estonia	5.5	-0.023	-1.293	0.247	1.540
	Finland	6.3	-0.024	-1.267	0.275	1.542
	France	7.4	-0.042	0.036	0.098	0.062
	Germany	7.5	-0.010	0.020	0.022	0.002
	Greece	7.7	0.005	-1.389	0.277	1.667
	Hungary	7.8	0.037	-1.235	0.168	1.402
	Ireland	4.6	-0.260	3.133	0.272	-2.861
	Italy	6.7	-0.034	0.197	0.050	-0.147
	Netherlands	2.8	-0.035	1.103	0.008	-1.095
	Poland	7.1	0.003	-0.821	0.150	0.971
	Portugal	7.7	0.006	-1.560	0.311	1.870
	Slovenia	4.4	-0.021	-1.235	0.195	1.430
	Spain	8.4	-0.062	-1.946	0.604	2.549
	Sweden	6.3	0.002	-1.335	0.220	1.555
	United Kingdom	5.4	-0.021	-1.492	0.266	1.758
EU-19	**Average**	**6.7**	**-0.025**	**-0.557**	**0.168**	**0.725**
	United States	**5.9**	**-0.172**	**1.100**	**0.259**	**-0.841**
Other	Canada	6.3	-0.008	1.011	-0.150	-1.160
OECD	Iceland	3.0	0.027	-0.214	-0.050	0.163
	Israel	6.1	0.000	0.070	-0.011	-0.080
	Japan	4.0	-0.005	0.115	0.001	-0.114
	Mexico	3.5	-0.028	1.365	-0.053	-1.418
	New Zealand	3.9	0.009	-0.209	-0.001	0.208
	Norway	2.6	0.005	0.413	-0.039	-0.452
	Switzerland	3.4	0.029	-0.689	-0.013	0.676

Note: All values are in %. Column 1 reports the national unemployment rate (source: ILO). Columns 2-5 report results of a simulation based on 116 countries for which sufficient data was available in year 2008, and where the matching elasticity is set to $\lambda = 0.6$. Column 2 is the 'reallocation effect'; Column 3 is the relative change in the unemployment rate; it is a weighted sum of the reallocation and expansion effects of Columns 2 and 4 by equations (22) or (32). Column 4 is the relative change in real wage; and Column 5 is the relative change in welfare obtained using Columns 3 and 4 according to the welfare criterion in (25). EU average reports averages weighted by population for 19 EU countries in our sample. Caution is required when interpreting results for New Zealand, Israel, and Ireland due to limited data on sectoral production shares (16, 17 and 24 sectors available out of 35, respectively).

Source: ILO and authors' calculations.

Table 5: Changes in unemployment rate, real wage, and welfare under TPP (in percent).

		(1) $\left(\frac{\sum_k s_{ik}^{TPP}\mu_k}{\sum_k s_{ik}^{2008}\mu_k} - 1\right)$	(2) $\left(\frac{u_i^{TPP}}{u_i^{2008}} - 1\right)$	(3) $\left(\frac{\omega^{TPP}}{\omega^{2008}} - 1\right)$	(4) $\left(\frac{\mathbb{W}^{TPP}}{\mathbb{W}^{2008}} - 1\right)$
TPP members	Canada	0.002	-3.897	0.650	4.547
	Japan	0.133	-4.684	0.155	4.839
	Mexico	0.001	-2.344	0.211	2.555
	New Zealand	-0.241	-5.247	1.142	6.390
	United States	-0.006	-0.248	0.053	0.301
EU-19	Austria	-0.003	0.112	-0.004	-0.116
	Belgium	-0.001	0.015	0.000	-0.016
	Czech Rep.	-0.001	0.070	-0.006	-0.076
	Denmark	0.000	0.046	-0.003	-0.049
	Estonia	-0.003	0.080	-0.005	-0.085
	Finland	-0.001	0.093	-0.012	-0.105
	France	-0.003	0.049	-0.003	-0.052
	Germany	0.001	-0.012	-0.001	0.011
	Greece	-0.002	0.099	-0.016	-0.115
	Hungary	0.001	0.025	-0.008	-0.034
	Ireland	0.010	-0.150	-0.006	0.144
	Italy	-0.001	0.022	-0.003	-0.025
	Netherlands	-0.003	0.098	0.000	-0.099
	Poland	-0.002	0.069	-0.007	-0.076
	Portugal	-0.007	0.118	-0.008	-0.126
	Slovenia	-0.001	0.088	-0.009	-0.096
	Spain	-0.001	0.047	-0.007	-0.055
	Sweden	0.000	0.058	-0.010	-0.068
	United Kingdom	0.001	0.029	-0.005	-0.035
EU-19	**Average**	**-0.001**	**0.037**	**-0.005**	**-0.042**
Other OECD	Iceland	0.010	0.424	-0.059	-0.483
	Israel	-0.001	0.057	-0.006	-0.063
	Norway	0.002	0.097	-0.012	-0.108
	Switzerland	-0.001	0.052	-0.002	-0.055

Note: All values are in %. The table reports results of a simulation based on 116 countries for which sufficient data was available in year 2008. The matching elasticity is set to $\lambda = 0.6$. Column 1 is the 'reallocation effect'; Column 2 is the relative change in the unemployment rate calculated as the weighted sum of columns 1 and 3 according to equations (22) or (32); Column 3 is the relative change in real wage; and column 4 is the relative change in welfare obtained using columns 2 and 3 according to equation (25). 'EU-19 Average' reports averages weighted by population for the 19 EU countries in our sample. Caution is required when interpreting results for New Zealand, Israel, and Ireland due to limited data on sectoral production shares (16, 17 and 24 sectors available out of 35, respectively).

Source: Authors' calculations.

Table 6: Changes in employment and unemployment rates with trade balanced throughout the world.

		(1)	(2)	(3)	(4)	(5)
		$b_i = \frac{E_i}{Y_i}$	$\left(\frac{\sum_k s_{ik}^{TB}\mu_k}{\sum_k s_{ik}^{2008}\mu_k} - 1\right)$	$\left(\frac{u_i^{TB}}{u_i^{2008}} - 1\right)$	$\left(\frac{\omega^{TB}}{\omega^{2008}} - 1\right)$	$\left(\frac{\mathbb{W}^{TB}}{\mathbb{W}^{2008}} - 1\right)$
$b < 1$	Austria	0.992	0.10	1.15	-0.33	-1.48
(surplus)	Canada	0.972	0.00	-8.24	1.23	9.48
	Czech Rep.	0.999	0.14	2.90	-0.62	-3.52
	Denmark	0.997	0.05	4.45	-0.47	-4.92
	Finland	0.932	0.02	-9.62	1.40	11.01
	Germany	0.927	-0.49	-2.71	1.59	4.30
	Ireland	0.834	-1.28	-17.78	4.88	22.65
	Japan	0.989	-0.19	1.77	0.25	-1.52
	Netherlands	0.938	0.06	-20.15	1.15	21.31
	Norway	0.813	-0.12	-70.94	4.53	75.47
	Sweden	0.946	0.01	-6.87	1.01	7.89
	Switzerland	0.951	0.11	-13.56	0.81	14.37
$b > 1$	Belgium	1.027	0.09	6.47	-1.27	-7.74
(deficit)	Estonia	1.116	-0.40	47.84	-5.25	-53.10
	France	1.026	0.08	5.44	-1.15	-6.58
	Greece	1.183	-0.15	46.65	-8.13	-54.78
	Hungary	1.009	0.17	1.50	-0.66	-2.17
	Iceland	1.056	0.76	23.44	-3.24	-26.68
	Israel	1.030	-0.11	8.83	-1.04	-9.87
	Italy	1.001	0.13	-1.07	-0.11	0.96
	Mexico	1.016	0.11	3.09	-0.49	-3.58
	New Zealand	1.016	-0.14	10.57	-0.64	-11.21
	Poland	1.058	0.28	12.98	-2.80	-15.78
	Portugal	1.129	0.12	26.09	-5.03	-31.12
	Slovenia	1.050	0.51	10.13	-2.15	-12.28
	Spain	1.078	0.72	4.07	-2.39	-6.46
	United Kingdom	1.062	0.46	6.89	-1.89	-8.78
	United States	1.057	0.00	1.92	-0.27	-2.19
EU-19	**Avg.**	**1.014**	**0.10**	**3.64**	**-0.90**	**-4.54**
Sample	**Avg.**	**1.021**	**0.03**	**2.09**	**-0.43**	**-2.52**

Note: Values in columns 2-5 are in %. Column 1 gives the trade imbalance in goods for year 2008 (source: IMF). Columns 2-5 report results of a simulation based on 105 countries for which sufficient data was available in year 2008, and where the matching elasticity is set to $\lambda = 0.6$. Column 2 is the 'reallocation effect'; Column 3 is the relative change in the unemployment rate calculated as the weighted sum of columns 2 and 4 according to equations (22) or (57); Column 4 is the relative change in real wage; and column 5 is the relative change in welfare obtained using columns 3 and 4 according to equation (25). EU and sample averages correspond to the averages weighted by population for 19 EU and 28 OECD countries in our sample, respectively. Caution is required when interpreting results for New Zealand, Israel, and Ireland due to limited data on sectoral production shares (16, 17 and 24 sectors available out of 35, respectively).

Source: IMF and authors' calculations.

Table 7: Gravity estimates

	Coeff.	Coeff.
ln(1+tariff)	-4.34	-3.17
	(0.205)	(0.174)
ln(D)	-1.59	-1.30
(ln *distance*)	(0.013)	(0.015)
CONT		0.66
(Contiguity)		(0.034)
LANG		0.62
(Common language)		(0.023)
COLON		0.78
(Common colonial exp.)		(0.034)
CURR		0.18
(Common currency)		(0.048)
RTA		0.52
		(0.028)
obs.	198,755	198,755
FE exporter-product	yes	yes
FE importer-product	yes	yes

Note: The table reports results of a gravity estimation using 181 exporter-countries, 139 importer-countries and 24 ISICRev3 tradable sectors for the year 2008. Two-way clustered standard errors are reported in brackets. All coefficients are statistically different from zero at the 1% level.

Source: Authors' calculations.

Table 8: Changes in unemployment rates and welfare for different values of matching elasticity λ.

	TTIP				**TPP**				**TB**			
	$\left(\frac{u_i^{TTIP}}{u_i^{2008}}-1\right)$		$\left(\frac{\mathbb{W}^{TTIP}}{\mathbb{W}^{2008}}-1\right)$		$\left(\frac{u_i^{TPP}}{u_i^{2008}}-1\right)$		$\left(\frac{\mathbb{W}^{TPP}}{\mathbb{W}^{2008}}-1\right)$		$\left(\frac{u_i^{TB}}{u_i^{2008}}-1\right)$		$\left(\frac{\mathbb{W}^{TB}}{\mathbb{W}^{2008}}-1\right)$	
$\lambda =\rightarrow$	0.3	0.9	0.3	0.9	0.3	0.9	0.3	0.9	0.3	0.9	0.3	0.9
AUT	-3.59	-0.68	3.761	0.740	0.18	0.08	-0.183	-0.081	9.00	-2.13	-9.65	1.91
BEL	0.57	0.75	-0.545	-0.748	0.00	0.02	-0.003	-0.020	21.12	-0.01	-23.50	-0.85
CAN	2.47	0.28	-2.693	-0.386	-12.48	-0.68	13.669	1.130	-22.84	-1.26	25.03	2.12
CHE	-0.40	-0.82	0.383	0.811	-0.01	0.07	0.004	-0.070	-34.04	-4.75	35.58	5.30
CZE	-3.79	-0.05	4.050	0.141	0.16	0.03	-0.169	-0.030	14.94	-2.20	-16.13	1.79
DEU	-0.25	0.11	0.292	-0.093	0.00	-0.02	0.000	0.015	-20.34	4.77	23.41	-3.70
DNK	-3.73	-0.65	3.895	0.707	0.05	0.04	-0.058	-0.038	16.37	-0.70	-17.25	0.38
ESP	-8.38	0.25	9.566	0.152	0.09	0.02	-0.106	-0.029	28.61	-6.10	-33.29	4.50
EST	-5.34	0.12	5.814	0.051	0.09	0.06	-0.093	-0.068	122.53	12.89	-100.00	-16.52
FIN	-5.11	0.09	5.641	0.098	0.18	0.04	-0.194	-0.051	-27.44	-1.75	30.06	2.70
FRA	-1.15	0.44	1.346	-0.376	0.07	0.04	-0.071	-0.041	18.65	-0.11	-20.89	-0.67
GBR	-6.05	0.06	6.573	0.121	0.09	0.00	-0.097	-0.003	37.59	-5.96	-41.26	4.69
GRC	-4.45	-0.29	4.975	0.477	0.21	0.04	-0.237	-0.052	132.22	8.55	-100.00	-14.10
HUN	-3.14	-0.57	3.470	0.687	0.09	-0.01	-0.098	0.001	9.71	-1.54	-11.12	1.11
IRL	-2.34	5.01	2.873	-4.823	-0.03	-0.20	0.018	0.200	-100.00	20.46	109.05	-17.13
ISL	1.04	-0.76	-1.124	0.729	1.82	-0.19	-1.916	0.149	111.50	-17.07	-100.00	14.84
ISR	0.21	0.01	-0.229	-0.022	0.11	0.03	-0.117	-0.032	24.74	2.68	-26.87	-3.36
ITA	-0.50	0.43	0.603	-0.395	0.04	0.01	-0.041	-0.016	0.51	-1.66	-0.74	1.59
JPN	0.10	0.13	-0.100	-0.125	-8.84	-3.35	9.159	3.454	-4.08	4.07	4.60	-3.91
MEX	2.45	0.89	-2.538	-0.923	-8.18	-0.40	8.598	0.536	16.94	-2.20	-17.96	1.88
NLD	0.82	1.19	-0.798	-1.182	0.06	0.11	-0.063	-0.112	-57.26	-4.82	59.52	5.60
NOR	1.47	-0.07	-1.537	0.037	0.36	-0.05	-0.373	0.041	-100.00	-6.90	108.64	9.97
NZL	-0.14	-0.23	0.137	0.225	-33.36	4.13	35.644	-3.369	25.00	4.48	-26.24	-4.91
POL	-2.68	-0.17	2.968	0.270	0.12	0.04	-0.131	-0.047	45.12	-1.26	-50.36	-0.65
PRT	-5.21	-0.32	5.827	0.532	0.16	0.10	-0.169	-0.101	80.85	2.69	-90.51	-6.09
SVN	-5.24	0.18	5.616	-0.050	0.20	0.03	-0.214	-0.033	52.52	-8.03	-56.64	6.58
SWE	-4.51	-0.24	4.944	0.392	0.15	0.01	-0.163	-0.019	-20.01	-1.17	21.94	1.85
USA	-2.94	2.48	3.448	-2.302	-1.24	-0.03	1.355	0.066	5.80	0.26	-6.32	-0.45

Note: All values are in %. Table reports results of simulations for TTIP and TPP counterfactuals (116 countries) and the TB counterfactual (105 countries) for 2008 baseline year using lower and upper bounds of lambda (0.3 and 0.9, respectively). Values below -100% have been rounded to -100%.
Source: Authors' calculations.