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Trade and Frictional Unemployment in the Global Economy

Céline Carrère (Geneva School of Economics and Management & CEPR)
Anja Grujovic (Geneva School of Economics and Management)
Frédéric Robert-Nicoud (Geneva School of Economics and Management, SERC, LSE & CEPR)

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Céline Carrère*
Anja Grujovic**
Frédéric Robert-Nicoud***

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* Geneva School of Economics and Management, and CEPR
** Geneva School of Economics and Management
*** Geneva School of Economics and Management, SERC, London School of Economics, and CEPR

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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
JEL Classifications: F15; F16; F17; J64

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.

[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 about, 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 the concerns of the latter 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), which is a combination of the sector-specific vacancy cost (which encompasses training costs in our static model) and of the sector-specific matching 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 misses the other half of the story whereby trade reforms reallocate resources such as labor across sectors. This *reallocation effect* has an impact on a country's unemployment rate if sectors have heterogeneous labor market frictions. We design an estimation strategy to measure these sector-specific labor market frictions in a theory-consistent way. The sector-specific coefficients that we estimate encompass several sources of labor market frictions, including sector-specific training costs (which are highly heterogeneous). We find substantial cross-sectoral variation in search-and-matching frictions. As an external validity check, we find that such sector-specific frictions correlate well with observed sectoral unemployment rates for which we have data (US manufactures).

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.[5] 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).

The main empirical contribution of this paper is to estimate the sector-specific labor market frictions in a structural manner for 35 tradable and non-tradable sectors. We find that our estimates correlate well with the observed US manufacturing sectoral unemployment rates and that the global economic crisis that started in 2008 ended up having a proportional impact on unemployment rates across manufacturing sectors. Both results are consistent with our formulation of the labor market frictions as the product of country-time and sector-specific effects.[6]

The normative contribution of the paper is to provide a rationale for the public's interest in 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 sectors and earning different wages in equilibrium (though *ex ante* expected wages are equalised across sectors). If society is averse to inequality (which can be the case even as workers are risk neutral),

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

[6] 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.

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 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 (2009). Finally, our paper contributes to the recent debate on the gains from trade sparked by Arkolakis, Costinot, and Rodríguez-Clare (2012).[8] Our model 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 contribute to the existing literature on four accounts. First, we complement papers that study labor market outcomes of various trade regimes. Brecher (1974) and Davidson, Martin, and Matusz (1988) set up Heckscher-Ohlin models in which the patterns of trade interact with domestic labor market frictions (such as a minimum wage or search frictions) to determine the equilibrium unemployment rate of trading countries. Davis (1998) emphasizes the terms of trade channel in a two-country framework building on Brecher (1974). Davidson, Martin, and Matusz (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 Armington, Ricardian, factor-specific, or intra-industry trade models. Felbermayr, Prat, and Schmerer (2011) and Heid and Larch (2013) embed labour market frictions into many-country heterogeneous firms and Armington trade models, respectively. [10] Our contribution to this literature is to build on these by developing a multi-sector, multi-country trade model. 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.

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).

[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 B 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 (*forthcoming*).

[9] See e.g. Antràs, de Gortari, and Itskhoki (2015), Burstein and Vogel (2015), Faber and Fally (2015), Helpman, Itskhoki, and Redding (2012), 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]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).

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 literatures on the economic effects of TTIP, TPP, and trade rebalancing.[11] Most of these papers display the expansion effect but none features our reallocation effect.

Finally, our application of a welfare criterion to a trade context is quite novel; we are aware of only two freshly minted papers using such criteria. Antràs, de Gortari, and Itskhoki (2015) 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 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

[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 (2014), Fontagné, Gourdon, and Jean (2013), Francois, Manchin, Norberg, Pindyuk, and Tomberger (2013), and Heid and Larch (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.

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.[12]

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.

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:

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

[12]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.

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.[13] For the sake of simplicity (and without loss of generality), we thus develop the more parsimonious model (without explicit occupations) below.

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}.

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, which is paid in terms of the domestic consumption bundle $\mathbb{U}_i$. In our setting, this parameter includes sector-specific training costs and such

[13] 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.

costs vary greatly across sectors. 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 defined as $E_{ik}(x) \equiv p_{ik}(x)\mathbb{Q}_{ik}(x)$. Using (1), we rewrite the expression for revenue as $E_{ik}(x) = p_{ik}(x)\varphi_{ik}(x)H_{ik}(x)$, which implies that revenue is linear in labor. 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

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

Henceforth we assume that workers can freely choose the sector in which they search for a job and that this choice is irreversible.[14] Remember that 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.[15] 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 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

[14] 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.

[15] It is straightforward to work out an extension of the model in which the representative consumer had constant relative risk aversion preferences, in which the level of utility would be $\mathbb{U}_i^{1-a}/(1-a)$, where $a \in (0, 1)$ is the constant rate of relative risk aversion. The ex-ante free-mobility across sector would thus imply $\ell_{ik} w_{ik}^{1-a} = w_i^{1-a}$, some $w_i > 0$. None of our qualitative results would be affected by this and we therefore impose $a = 0$ in what follows for simplicity.

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.[16] 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 $\gamma^{-1} p_{ik} \xrightarrow{p} w_{ik}/\varphi_{ik}$, where $\gamma > 0$ is defined below.[17] Using the no-arbitrage condition (12) to substitute for w_{ik} in this expression yields

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

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

$$\omega_i^0 = \left[\frac{1}{\gamma}\prod_{k=1}^{K} (\varphi_{ik}\mu_{ik})^{\alpha_{ik}}\right]^{\frac{1}{\lambda}}, \tag{14}$$

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

[16] 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.

[17] 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.

unemployment rate as the fraction of the working population that has not found a job in equilibrium:

$$u_i \equiv 1 - \frac{1}{\bar{L}_i} \sum_{k=1}^{K} H_{ik} = 1 - \sum_{k=1}^{K} \frac{L_{ik}}{\bar{L}_i} \ell_{ik}, \tag{15}$$

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 (15) yields

$$u_i^0 = 1 - \left(\omega_i^0\right)^{1-\lambda} \bar{\mu}_i^0, \quad \text{where} \quad \bar{\mu}^0 \equiv \sum_{k=1}^{K} \alpha_{ik} \mu_{ik} \tag{16}$$

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 (14) and (16) to establish the following result:

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 (14). (**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 (16). 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 (16) 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*. Insofar as consumption is equal to production in autarky, it makes sense that one is the flip side of the other, as established in Proposition 1. Things fundamentally change with trade because 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

There are I countries in the world. 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

$$p_{jk}(x) = \min_{i} \quad c_{ijk}(x). \tag{17}$$

Let $c_i \equiv w_i^{\lambda}\mathbb{P}_i^{1-\lambda}$ denote the 'input cost' in country i.[18] Let also

$$t_{ijk} \equiv \frac{\tau_{ijk}}{\varphi_{ik}\mu_{ik}}c_i \tag{18}$$

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

$$T_{jk} \equiv \left(\sum_{i'=1} t_{i'jk}^{-\theta}\right)^{-\frac{1}{\theta}} \tag{19}$$

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 (17) that bilateral trade flows (in value) at the industry level obey the following gravity equation:

$$E_{ijk} = \left(\frac{t_{ijk}}{T_{jk}}\right)^{-\theta} \alpha_{jk}E_j. \tag{20}$$

The first term in the right-hand side above is country i's market share in country j's market k.

Inspection of (18) and (20) 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

[18]Combining (11), (12), and (13), we obtain $c_{ik} = c_i/\mu_{ik}$.

net of training costs μ_k; see (18). Consequently, they cannot be identified separately using trade flow data as per (20). Second, wages do not enter (18) 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, (un)employment, and utility

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 $E_{ik} = 2w_{ik}H_{ik} = 2w_iL_{ik}$. 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 (15) as

$$\ell_i \equiv 1 - u_i = \omega_i^{1-\lambda}\bar{\mu}_i, \quad \text{where} \quad \bar{\mu}_i \equiv \sum_{k=1}^{K} s_{ik}\mu_{ik} \tag{21}$$

is the weighted average matching efficiency in country i evaluated at the trade equilibrium.

In the remainder of this section we consider two comparative statics exercises. They set the stage for the counterfactual exercises of Section 7 by emphasizing the mechanisms at work in the model. We start with the consequences of marginal changes.

Marginal changes. We use hats to denote relative changes. Consider a marginal trade reform that influences (real) wages and employment rates. Total differentiation of (21) yields

$$\hat{\ell}_i = (1-\lambda)\hat{\omega}_i + \frac{1}{\bar{\mu}_i}\text{Cov}\left(\hat{s}_{ik}, \mu_{ik}\right), \tag{22}$$

where

$$\text{Cov}\left(\hat{s}_{ik}, \mu_{ik}\right) \equiv \sum_{k=1}^{K} \hat{s}_{ik}\left(\mu_{ik} - \bar{\mu}_i\right)$$

is the covariance between the sector-specific matching efficiencies and the shift in production shares.[19] Under non-discriminatory trade liberalisation and in the absence of trade diversion, the shift in production shares could be interpreted as a shift in *revealed comparative advantage*.

[19]Note that the average variation in production shares is zero.

Inspection of (22) 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 outcome, which was absent in the autarky equilibrium, arises because trade allows for the uncoupling of consumption and production bundles.

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, there are differential effects on the individuals themselves. To the extent that gains from trade are not redistributed through unemployment benefits, there are winners and losers in terms of employment.[20]

Discrete changes. We now use (21) to compare two equilibriums – say, the actual equilibrium and a counterfactual one (e.g. a free trade agreement, balanced trade). Variables pertaining to the current equilibrium are un-superscripted; we use the superscript 'CF' for the counterfactual equilibrium.

The counterfactual domestic employment rate relative to its current level is equal to

$$\frac{\ell_i^{CF}}{\ell_i} = \left(\frac{\omega_i^{CF}}{\omega_i}\right)^{1-\lambda} \left[1 - \frac{\text{Cov}\left(s_{ik} - s_{ik}^{CF}, \mu_{ik}\right)}{\bar{\mu}_i}\right], \tag{23}$$

where

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

If the counterfactual is autarky then $s_{ik}^0 = \alpha_{ik}$ and $\text{Cov}(\cdot) \equiv \sum_k \left(s_{ik} - \alpha_{ik}\right)\left(\mu_{ik} - \bar{\mu}_i\right)$ is the covariance between the sectoral matching efficiencies and a theory-consistent measure of *revealed comparative advantage* of country i. To see this, note that s_{ik} is greater than α_{ik} in exporting sectors whereas $s_{ik} < \alpha_{ik}$ holds in import-competing sectors. Of course, actual patterns of trade reflect not only technology-based source of comparative advantage but also heterogeneous bilateral trade barriers due to physical geography (e.g. distance) and discriminatory trade policies. But it is safe to assert that observed trade patterns reflect at least in part the comparative advantages of countries when the benchmark is autarky.

With this note of caution in mind, we can thus establish the following:

[20]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. More on this in subsection 5.3 below.

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:*

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

*(**ii**) The actual equilibrium employment rate in country i (ℓ_i) is greater than the counterfactual employment rate (ℓ_i^{CF}) if the actual allocation yields higher real wages and if it allocates more resources to sectors with high matching efficiencies than the counterfactual allocation does:*

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

Proof. The proof of (**ii**) is by inspection of (23); (**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. ■

Of course, this Proposition leaves open a situation 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 the 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 (18), (19), and (20). 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.

5.3 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 inequality. 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

$$\frac{\mathbb{W}^{CF}}{\mathbb{W}} - 1 = \frac{\omega^{CF}/u^{CF}}{\omega/u} - 1 = \frac{\omega^{CF}}{\omega} - \frac{u^{CF}}{u}, \tag{24}$$

where the second equality is a first-order approximation. In Appendix B, 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.[21] There, we also show that Sen's (1976) alternative welfare criterion puts much less weight on unemployment changes than Atkinson's. 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 differential effects on the individuals themselves. 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.

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

[21]Empirically, Stern (1977) (for the UK) and Young (1990) (for the US) find degrees of inequality aversion in the range $[1.61 - 1.97]$.

counterfactual scenarios in Section 7.

6.1 Data

Bilateral sector-level trade data are obtained for 181 exporting countries and 139 importing countries in 2008 from CEPII's BACI database. Bilateral sector-level tariffs are taken from the TRAINS (UNCTAD) 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). Sectoral production data is taken from OECD's Stan database (ISICRev3) and is available for 25 OECD countries over the period 2001-2008, henceforth 'OECD-25'. We classify data to 35 ISICRev3 sectors (out of which 24 produce tradable goods). Table 1 lists the sectors. Both the sector-specific and the aggregate country-level unemployment rates are obtained using data from the ILO Key Indicators of the Labor Market (KILM) database. In computing the sector-specific unemployment rate, we use the number of unemployed persons whose previous employment was in that sector (more on this below). The trade balance for year 2008 is sourced from World Bank Development Indicators (WDI) database.

6.2 Estimation and empirical strategy

We aim to quantify the employment consequences of any given counterfactual. For convenience, we rewrite (23) as

$$\frac{\ell_i^{CF}}{\ell_i} = \left(\frac{\omega_i^{CF}}{\omega_i}\right)^{1-\lambda} \frac{\sum_{k=1}^{K} s_{ik}^{CF} \mu_{ik}}{\sum_{k=1}^{K} s_{ik}\mu_{ik}},$$

where, as before, the un-superscripted and superscripted variables pertain to the current and counterfactual allocations, respectively.

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}^{CF} and real per capita GDP ω_i^{CF}. 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);
- 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

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 is 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). However, 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 a source of comparative advantage, a possibility that is ruled out by our identifying assumption. Reassuringly, 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}. Indeed, Chor (2010) finds that comparative advantage explains only a small fraction of the residual variation of bilateral trade flows; much is explained by the country and sector fixed effects (μ_k and μ_i in our notation).[22] Furthermore, labor market institutions are quantitatively the smallest among several sources of comparative advantage that Chor (2010) is simultaneously testing (other sources include financial market institutions, product market institutions, and relative factor endowments). All these lend support to the idea that our specification captures the first-order effects of our reallocation channel.

We can now estimate the μ_k's in a structural way as follows. 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 imposing a country-year fixed effect $FE_{it} = \ln\left(\mu_{it}\omega_{it}^{1-\lambda}\right)$ and a sector-specific fixed effect $FE_k = \ln \mu_k$. That is, we run the regression $\ln \ell_{ikt} = FE_{it} + FE_k + \text{error}_{ikt}$. In computing the left-hand side variable, we use sectoral unemployment data for 25 OECD countries for the period 2001-2008, sourced from the KILM database, where the sectoral unemployment rate is defined as $1 - \ell_{ikt}$.[23] Sectoral unemployment data is available for 15 aggregate sectors (see list in Table 1), of which one is the manufacturing sector.

Figure 1 provides a graphical representation of the 90% confidence intervals of each sector-specific

[22]Note, though, that we do allow for any source of comparative advantage to play a role in the determination of trade flows when estimating the trade elasticities and other gravity coefficients in subsection 6.4 below.

[23] 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 who are searching for a job in sector k but are unable to form a match, i.e. $u_{ikt} = 1 - \ell_{ikt}$.

matching efficiency estimated on a sample of 1,624 observations for the 15 aggregate sectors. The highest matching efficiency appears to be in 'Financial intermediation' and 'Electricity, gas and water supply' while the lowest estimated μ_k's are found in sectors such as 'Construction', 'Hotels and restaurants' or 'Agriculture, hunting and forestry.'

As we are particularly interested in estimating relative matching efficiencies of different manufacturing sectors, we estimate these using the definition of $\bar{\mu}$ in (21). The model predicts that the average matching efficiency of a given sector (in this case the aggregate manufacturing sector) is given by (omitting country and time subscripts for simplicity)

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

where μ_m and s_m are, respectively, the matching efficiency and the production share of each of the 21 manufacturing sectors contained within the aggregated manufacturing sector (see Figure 1), and $\sum_m s_m = 1$. The matching efficiencies of all 35 sectors are then non-linearly estimated in one step on the same sample of 1,624 observations and so we replace FE_k by $\sum_m s_m \mu_m$ for $k = manuf$ in the regression $\ln \ell_{ikt} = FE_{it} + FE_k + \text{error}_{ikt}$.

Table 2, column 3, reports our estimates of sector-specific matching efficiencies for 35 sectors. Most values are significant at the 1% significance level. The estimated μ_k's range from 0.033 for 'Wood and products of wood and cork' to 1.49 for 'Non-metallic mineral products' and 'Printing and publishing.' Furthermore, these sector-specific matching efficiencies have a high predictive power, as 45% of the R^2 is explained by the sector-specific fixed effect, while the other 55% is explained by the country-time fixed effect.

As an external validity test of this empirical strategy, we correlate the estimated values of the efficiencies of the 21 manufacturing sectors computed from the OECD-25 countries with available observable sector-specific employment rates that are provided for the US by the Bureau of Labor Statistics. Our model and our identifying assumption lead us to predict a positive and stable relationship. The BLS database includes a decomposition of employment rates for 12 manufacturing sectors for several years. We thus aggregate some of our 21 μ_m's in order to correspond to the 12 BLS manufactured sectors as a weighted average of the sub-sectors, where the weights are given by the US production shares in the relevant years. The correlation and rank correlation between our estimates of μ_m and the employment rates $\ell_{US,m}$ are reported in Table 3. The correlations remain stable throughout the financial crisis as reflected in the quasi-parallel translation of the 2007, 2008 and 2009 linear fits reported in Figure 2. That is, we find that labor matching efficiency is pro-cyclical, as in Barnichon and Figura (2015)'s estimates of an aggregate matching function.

These patterns in Table 3 and Figure 2 are reassuring on three counts. First, the correlations are strong (over 0.6 on average). Second, since all correlations are between a US variable and an OECD average variable, this suggests that there is no discernible sector-country component in the matching efficiencies. Third, the stability of the relationship over time seems to rule out sector-time variations, which vindicates our identifying assumption. Note that 2009 is an out-of-sample and atypical year; yet, the correlation between the μ_m's and the $\ell_{US,m}$'s is the same as in the previous years in a statistical sense.

6.4 Estimation of trade elasticities

We use a gravity equation to estimate the trade elasticity with respect to bilateral trade costs. Using expressions (18), (20), and (19), and taking logs yields

$$\ln E_{ijk} = -\theta \ln \tau_{ijk} - \theta \ln \kappa_{ik} - \ln \sum_{i'=1}^{I} (\tau_{i'jk}\kappa_{i'k})^{-\theta} + \ln(\alpha_{jk}E_j), \tag{25}$$

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

$$\kappa_{ik} \equiv \frac{w_i^{\lambda}\mathbb{P}_i^{1-\lambda}}{\varphi_{ik}\mu_{ik}} \tag{26}$$

captures exporter-sector unobservables.

Let $\tau_{ijk} \equiv (1+\text{tariff}_{ijk})D_{ij}^{\delta_D} e^{(\delta_{rta}RTA_{ij}+\delta_{cont}CONT_{ij}+\delta_{lang}LANG_{ij}+\delta_{colon}COLON_{ij}+\delta_{curr}CURR_{ij})}$, 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 (25) as a gravity equation:

$$\begin{aligned} \ln E_{ijk} &= \beta_{tariff} \ln(1+\text{tariff}_{ijk}) + \beta_D \ln(D_{ij}) + \beta_{rta}RTA_{ij} + \beta_{cont}CONT_{ij} + \beta_{lang}LANG_{ij} \\ &+ \beta_{colon}COLON_{ij} + \beta_{curr}CURR_{ij} + FE_{ik} + FE_{jk} + \epsilon_{ijk}, \end{aligned} \tag{27}$$

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 24 tradable ISIC Rev3 sectors producing tradable goods for pre-crisis year 2008. We obtain $\hat{\theta} = -\hat{\beta}_{tariff} = 3.17$ (See Appendix C 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).[24]

[24] The median and the mean coefficients of 744 statistically significant estimates (obtained from 32 papers) of the

7 Unemployment and welfare effects under various scenarios

In this section we compute 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. Appendix D describes the methodology in details.

Counterfactual changes in real wages, unemployment rates, and welfare for both FTA scenarios (TTIP and TPP) are carried out under the assumption that tariffs (as well as other, non-tariff barriers) are eliminated among all FTA members in both agricultural products and manufactures. In the trade balance scenario (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 perform our calculations by iteration using Matlab. Appendix D provides details.

Throughout all scenarios, we set the matching elasticity at $\lambda = 0.6$; this value is the midpoint of Petrongolo and Pissarides' (2001) "plausible range" of $[0.5 - 0.7]$. We run sensitivity tests in Appendix E and our qualitative results are quite robust to this parametrization.

7.1 The Transatlantic Trade and Investment Partnership (TTIP) scenario

The Transatlantic Trade and Investment Partnership (TTIP) is currently being negotiated between the European Union and the United States and aims at removing trade barriers between the EU and the US (including tariffs, unnecessary regulations, and restrictions on investment). An independent impact report commissioned by the European Commission (Francois, Manchin, Norberg, Pindyuk, and Tomberger, 2013) suggests that trade liberalisation will necessarily lead to job creation due to the productivity gains and the increases in economic activity. However, our model suggests that trade agreements could also lead to higher unemployment if workers are reallocated towards sectors with higher-than-average labor market frictions.

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 C) among all TTIP countries.

We report the results for 28 OECD countries in Table 4 and Figure 3.[25] All values are in %. The top

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 C for detailed estimation statistics).

[25] We report results for our OECD-25 sample of countries as well as for New Zealand, Israel, and Ireland despite limited

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' ($\frac{\omega_i^{FTA}}{\omega_i^{2008}}$). Finally, column five reports changes in welfare as measured by (24): it is approximately equal to the difference between columns 4 and 3. Figure 3 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 3 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 (24) equal to zero. The mathematical expression of the iso-welfare line is given by $\frac{\omega^{FTA}}{\omega^{2008}} = \frac{u^{FTA}}{u^{2008}}$. 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 3 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-Clare 2014).[26] 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 3. 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. While trade liberalisation may engender growth of real wages due to increased production and reduced import prices, it may also lead to a restructuring of production and thereby a reallocation of workers across sectors. Insofar as sectors are heterogeneous in their ability to match workers to jobs, the overall unemployment rate may fall or rise. 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,

data on sectoral production shares. We do not have access to employment 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.

[26]For instance, our real wage effects are lower than those reported in Felbermayr, Heid, Larch, and Yalcin (2014) 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.

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 (24) 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). Annex B 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^{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 2); 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 (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.[27]

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.

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

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

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 and find that they correlate well with observed US-sectoral employment rates for which we have 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.

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.'

A current limitation of our counterfactual exercises is that our framework, as all settings fulfilling the conditions laid out in Arkolakis, Costinot, and Rodríguez-Clare (2012), yields small real wage effects. Relaxing such conditions adds novel margins of adjustments and tends to yield higher estimated effects (Arkolakis and Esposito, 2014; Head, Mayer, and Thoenig, 2014; Melitz and Redding, 2015). For instance, the elasticity of welfare with respect to trade openness increases when accounting for input-output linkages among sectors (Costinot and Rodríguez-Clare, 2014). Under the assumption that input-output coefficient are identical and constant, the reallocation effect would remain unaffected by allowing for this extension. A natural extension of our current work would relax this Leontief assumption by e.g. using trade-in-value-added data.

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

$$c_{is} \equiv \mathbb{P}_i \left(\frac{\ell_{is}^{\lambda}}{\mu_{is}} \right)^{\frac{1}{1-\lambda}} \tag{28}$$

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:

$$w_{iks}(x) = w_{is} = c_{is}. \tag{29}$$

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:

$$w_i = \ell_{is} w_{is}. \tag{30}$$

Combining this expression with (28) and (29) yields:

$$\frac{w_i}{\mathbb{P}_i} = \left(\frac{\ell_{is}}{\mu_{is}}\right)^{\frac{1}{1-\lambda}}. \tag{31}$$

This implies that occupations with high matching efficiency μ_{is} have higher employment rate and, by the no-arbitrage condition (30), lower wages.

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

$$\forall s, \tilde{s} : \frac{H_{iks}}{H_{ik\tilde{s}}} = \frac{a_{ks}}{a_{k\tilde{s}}} \frac{\mu_{is}}{\mu_{i\tilde{s}}}. \tag{32}$$

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 (32). Specifically:

$$h_{iks} \equiv \frac{H_{iks}}{\sum_{\tilde{s}} H_{ik\tilde{s}}} = \frac{\mu_{is} a_{ks}}{\sum_{\tilde{s}} \mu_{i\tilde{s}} a_{k\tilde{s}}} \tag{33}$$

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:

$$s_{iks} \equiv \frac{L_{iks}}{\sum_{\tilde{s}} L_{ik\tilde{s}}} = a_{ks}. \tag{34}$$

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 (31) and (34) that the average employment rate in a sector k is equal to:

$$\bar{\ell}_{ik} \equiv \sum_{s=1}^{S} s_{iks}\ell_{is} = \left(\frac{w_i}{\mathbb{P}_i}\right)^{1-\lambda} \sum_{s=1}^{S} a_{ks}\mu_{is} = \left(\frac{w_i}{\mathbb{P}_i}\right)^{1-\lambda} \bar{\mu}_{ik}, \tag{35}$$

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 (28), (29) and (33):

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

Combining with (35) 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: Welfare

In this appendix we establish that (24) 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. In our model, b is set to zero.

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:

$$\mathbb{W}(\eta) \equiv \left[\sum_{k=1}^{K} s_k\ell_k\omega_k^{1-\eta} + (b\omega)^{1-\eta}u\right]^{\frac{1}{1-\eta}}, \tag{36}$$

where $\eta \in \mathbb{R}$ is the *relative rate of inequality aversion*; $\eta = 0$ for Bentham and $\eta = +\infty$ for Rawls.[28] Using the no-arbitrage condition (12), we can rewrite (36) as

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

where $\bar{\ell}_\eta \equiv \sum_k s_k \ell_k^\eta$ is an *inequality-adjusted* measure of the employment rate ($\bar{\ell}_\eta < \ell$ iff $\eta > 0$).[29]

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 (36) balances average real wages with (un)employment concerns and the higher η, the higher the weight 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

$$\frac{\mathbb{W}^{CF}}{\mathbb{W}} - 1 = \frac{\omega^{CF}}{\omega} - \frac{u^{CF}}{u}$$

as in (24). 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 generally, for any $\eta > 1$, (24) generalizes to

$$\frac{\mathbb{W}^{CF}}{\mathbb{W}} - 1 = \frac{\omega^{CF}}{\omega} - \frac{1}{\eta - 1} \frac{u^{CF}}{u}$$

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 $\eta < 1$, (24) becomes

$$\frac{\mathbb{W}^{CF}}{\mathbb{W}} - 1 = \frac{\omega^{CF}}{\omega} + \frac{1}{1 - \eta} \frac{\bar{\ell}_\eta^{CF}}{\bar{\ell}_\eta};$$

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

$$\mathbb{W} = \omega(1 - \mathbb{G}), \tag{37}$$

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

[29] 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.

where $\mathbb{G}$ is the Gini coefficient of earnings inequality. This criterion satisfies several desirable properties.[30] Like in (36), $\mathbb{W}$ 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 (37) and computing welfare changes yields

$$\frac{\mathbb{W}^{CF}}{\mathbb{W}} - 1 = \frac{\omega^{CF}}{\omega} + \frac{\ell^{CF}}{\ell} + \frac{1 - \mathbb{G}_\ell^{CF}}{1 - \mathbb{G}_\ell} - 3, \tag{38}$$

where $\ell^{CF} \equiv 1 - u^{CF}$ 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 (24).

Another way to emphasize the similarity between Sen and Atkinson's criteria is to consider the special case $u = \ell = 1/2$ and $\mathbb{G}_\ell^{CF} = \mathbb{G}_\ell$. In this case, (38) and (24) 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 (24) puts a higher weight on unemployment changes than does Sen's criterion in (38).

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 4 the comparison between Atkinson's and Sen's welfare criteria obtained under the TTIP scenario. Juxtaposing this graph to Figure 3, 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 C: Gravity estimation results

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

[30]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.

Appendix D: 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^{CF}, $\mathbb{P}_i^{CF}$, and $\{s_{ik}^{CF}\}_k$, 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}^{FTA}/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^{FTA}, and (iv) exporter-sector unobservables, κ_{ik}^{FTA}'s, which we obtain as follows:

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

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

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,

$$ED_i \equiv \sum_{j=1}^{J} \sum_{k=1}^{K} \left(\frac{\hat{t}_{ijk}}{\hat{T}_{jk}} \right)^{-\theta} \alpha_k E_j - E_i, \tag{39}$$

where $\hat{t}_{ijk} = \hat{\tau}_{ijk}\hat{\kappa}_{ik}$ and $\hat{T}_{jk} = (\sum_{i'} \hat{t}_{i'jk}^{-\theta})^{-1/\theta}$ by (19). 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'.[31] 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

$$ED_i^{FTA} \equiv \sum_{j=1}^{J}\sum_{k=1}^{K}\left(\frac{t_{ijk}^{FTA}}{T_{jk}^{FTA}}\right)^{-\theta}\alpha_k E_j^{FTA} - E_i^{FTA} \tag{40}$$

is equal to zero, all i.

Let $\tilde{x} \equiv x^{FTA}/x$ 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 $E_j^{FTA} = \tilde{E}_j \times E_j^C$. Second, $t_{ijk}^{FTA} = \hat{t}_{ijk}\tilde{\tau}_{ijk}\tilde{\kappa}_{ik}$ by (18) and (26). Using the latter, it turns out that the ratio $\tilde{\kappa}$ is origin-specific (more on this below) and so we write $t_{ijk}^{FTA} = \hat{t}_{ijk}\tilde{\tau}_{ijk}\tilde{\kappa}_i$. Finally, the gravity variables other than the RTA_{ij} dummy are time-invariant; therefore,

$$\tilde{\tau}_{ijk} = \begin{cases} \frac{1}{1+\text{tariff}_{ijk}} e^{\hat{\delta}_{rta}} & \text{if} \quad i,j \in \{\text{FTA member}\} \\ 1 & \text{otherwise.} \end{cases} \tag{41}$$

Using these relationships, we rewrite (40) as

$$ED_i^{FTA} \equiv \sum_{j=1}^{J}\sum_{k=1}^{K}\left(\frac{\hat{t}_{ijk}\tilde{\tau}_{ijk}\tilde{\kappa}_i}{\sum_{i'}\hat{t}_{i'jk}\tilde{\tau}_{i'jk}\tilde{\kappa}_{i'}}\right)^{-\theta}\alpha_k E_j^C\tilde{E}_j - E_i^C\tilde{E}_i, \tag{42}$$

where the $\hat{t}_{ijk}$'s are the same as in (39) and the E_i^C's are the excess-demand minimizing E_i's of (39). 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.

(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 (26). Income being proportional to wages in our Ricardian model, we obtain $\tilde{w}_i = \tilde{E}_i$ and thus

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

[31] We may rewrite (39) 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.

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 (41), 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 (40), and

$$e\tilde{\kappa}_i \equiv \tilde{E}_i^{\hat{\lambda}} \widetilde{\mathbb{P}}_i^{1-\hat{\lambda}} - \tilde{\kappa}_i = \tilde{E}_i^{\hat{\lambda}} \prod_{k=1}^{K} \left[\frac{\sum_{j=1}^{J} \left(\hat{\tau}_{ijk}\hat{\kappa}_{jk}\tilde{\tau}_{ijk}\tilde{\kappa}_j\right)^{-\theta}}{\sum_{j=1}^{J} \left(\hat{\tau}_{ijk}\hat{\kappa}_{jk}\right)^{-\theta}} \right]^{-\frac{\alpha_k}{\theta}(1-\hat{\lambda})} - \tilde{\kappa}_i, \tag{43}$$

where $\hat{\lambda} = 0.6$ 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^{FTA}/E_i in (42) and of $e\tilde{\kappa}_i$ in (43). 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 (41) and the estimated ratios $\tilde{\mathbf{E}}$ and $\tilde{\kappa}$:

$$\tilde{E}_{ijk} = \begin{cases} \tilde{\tau}_{ijk}^{-\hat{\theta}} \tilde{\kappa}_i^{-\hat{\theta}} \dfrac{\sum_{i'=1}^{I} \left[\hat{\tau}_{i'jk}\hat{\kappa}_{i'k}\right]^{-\hat{\theta}}}{\sum_{i'=1}^{I} \left[\hat{\tau}_{i'jk}\hat{\kappa}_{i'k}\tilde{\tau}_{i'jk}\tilde{\kappa}_{i'}\right]^{-\hat{\theta}}} \tilde{E}_j & \text{if} \quad k \in \mathbb{K}_T \\ \tilde{E}_i & \text{if} \quad k \in \mathbb{K}_N \quad \text{and} \quad j = i \\ 0 & \text{if} \quad k \in \mathbb{K}_N \quad \text{and} \quad j \neq i \end{cases} \tag{44}$$

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

$$s_{ik}^{FTA} = \frac{\sum_{j=1}^{J} E_{ijk}\tilde{E}_{ijk}}{\sum_{k'=1}^{K} \sum_{j=1}^{J} E_{ijk'}\tilde{E}_{ijk'}}, \tag{45}$$

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

$$\frac{\ell_i^{FTA}}{\ell_i} = \left(\frac{\tilde{E}_i}{\widetilde{\mathbb{P}}_i}\right)^{1-\lambda} \frac{\sum_k s_{ik}^{FTA}\mu_k}{\sum_k s_{ik}\mu_k}. \tag{46}$$

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 (39) as

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

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 (42):

$$ED_i^{TB} \equiv \sum_{j=1}^{J}\sum_{k=1}^{K}\left(\frac{\hat{t}_{ijk}\tilde{\kappa}_i}{\sum_{i'}\hat{t}_{i'jk}\tilde{\kappa}_{i'}}\right)^{-\theta}\alpha_k E_j^{TB}\tilde{E}_j - E_i^{TB}\tilde{E}_i. \tag{47}$$

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

$$e\tilde{\kappa}_i = \tilde{E}_i^{\hat{\lambda}}\prod_{k=1}^{K}\left[\frac{\sum_{j=1}^{J}\left(\hat{\tau}_{ijk}\hat{\kappa}_{jk}\tilde{\kappa}_j\right)^{-\theta}}{\sum_{j=1}^{J}\left(\hat{\tau}_{ijk}\hat{\kappa}_{jk}\right)^{-\theta}}\right]^{-\frac{\alpha_k}{\theta}(1-\hat{\lambda})} - \tilde{\kappa}_i. \tag{48}$$

We solve for the vectors $\mathbf{E}$ and $\tilde{\kappa}$ that jointly minimize the sums of squares in (47) and (48).

Finally, we compute the counterfactual (balanced trade) trade flows, labor shares, and the employment rates as in (44), (45), and

$$\frac{\ell_i^{TB}}{\ell_i} = \left(\frac{\tilde{E}_i}{\tilde{\mathbb{P}}_i}\right)^{1-\lambda}\frac{\sum_k s_{ik}^{TB}\mu_k}{\sum_k s_{ik}\mu_k}, \tag{49}$$

respectively.

Appendix E: 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 (23). 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.

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Figures

Figure 1: Estimated sector-specific labor market matching efficiencies (μ_k's) with 90% confidence intervals, for 15 aggregate sectors with available unemployment rate data

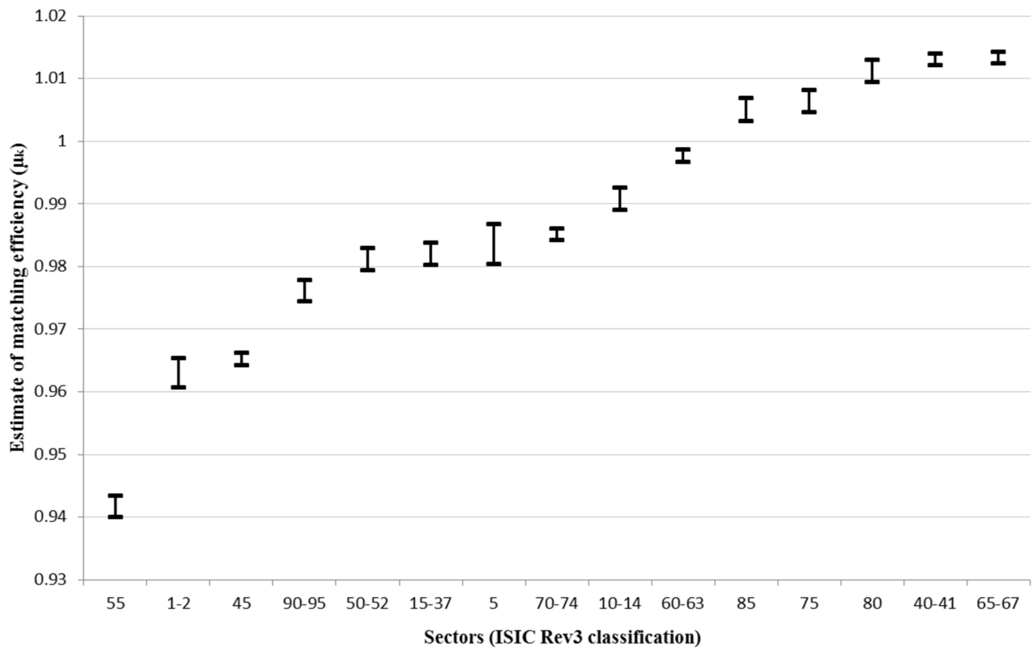
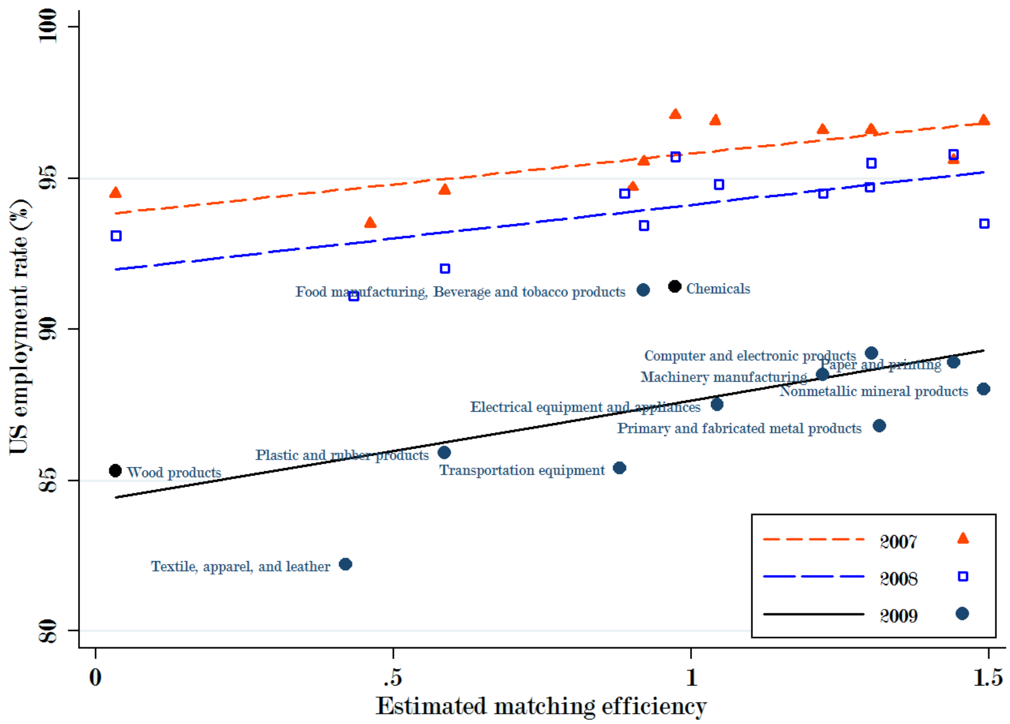
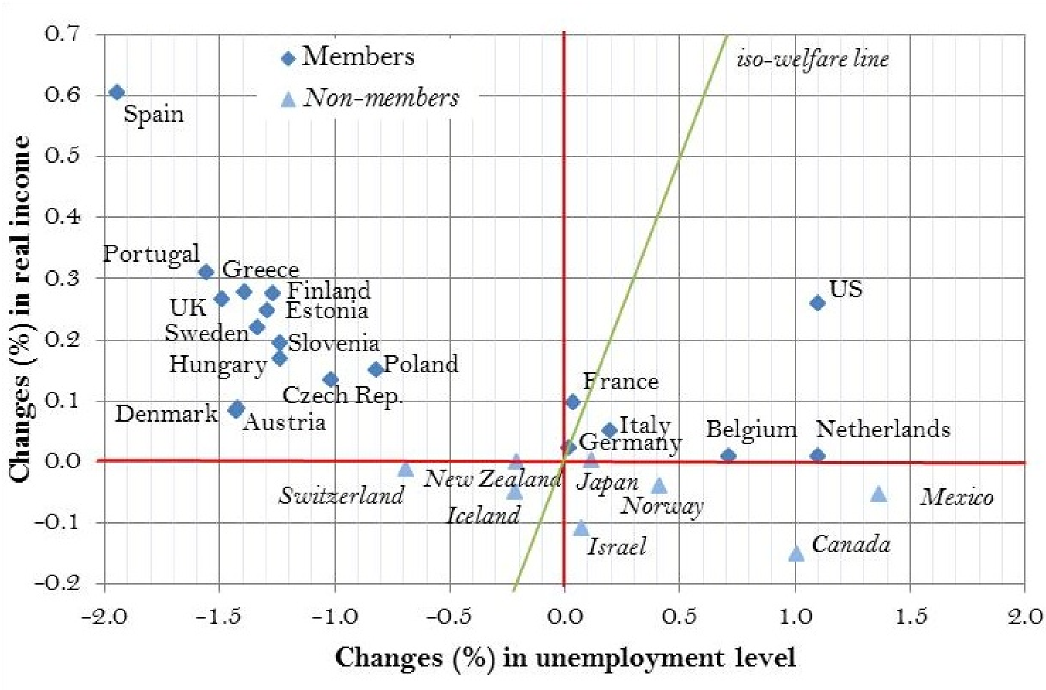


Figure 2: Correlation between the estimated μ_k's and the US employment rates for 12 BLS manufacturing sectors



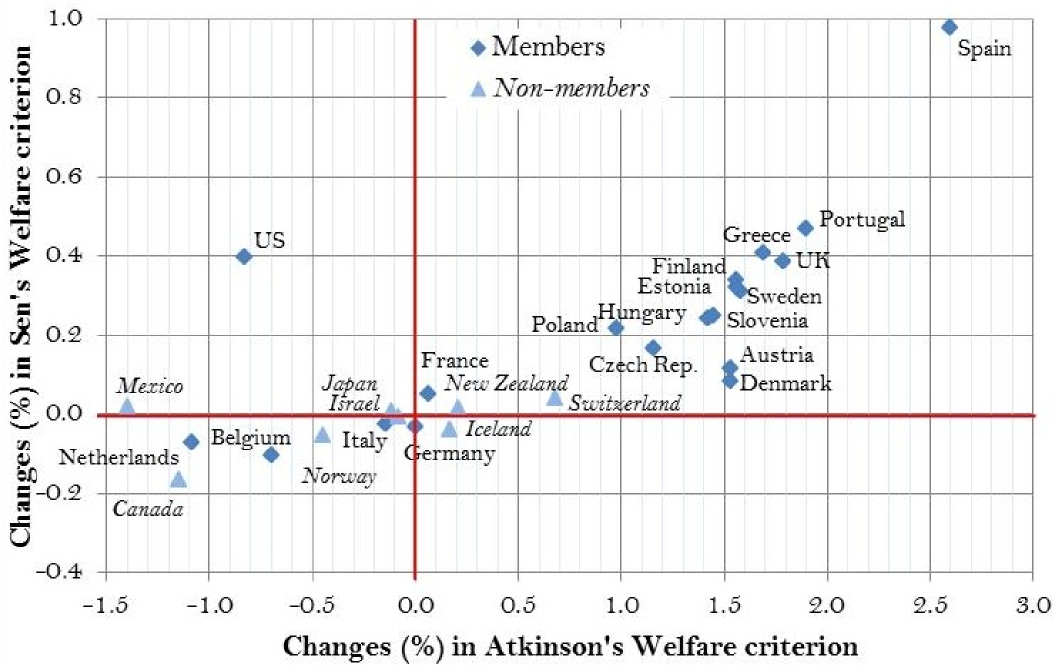
Note: Figure shows the linear fit between matching efficiencies estimated for our OECD-25 sample of countries and the US sectoral employment data (sourced from the US Bureau of Labor Statistics) for 12 manufacturing sectors for which sector-specific employment data was available, for years 2007-2009.

Figure 3: 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).

Figure 4: Relative welfare changes under the TTIP scenario according to Sen's and Atkinson's criteria



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

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

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

Note: The table displays estimates of matching efficiencies for 35 sectors classified according to ISICRev3. 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).

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: 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.

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

		(1)	(2)	(3)	(4)	(5)
		u_i^{2008}	$\left(\frac{\sum_k s_{ik}^{TTIP}\mu_k}{\sum_k s_{ik}^{2008}\mu_k} - 1\right)$	$\left(\frac{u_i^{TTIP}}{u_i^{2008}} - 1\right)$	$\left(\frac{\omega^{TTIP}}{\omega^{2008}} - 1\right)$	$\left(\frac{\mathbb{W}^{TTIP}}{\mathbb{W}^{2008}} - 1\right)$
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 (21) or (46). 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 (24). 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).

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

		(1)	(2)	(3)	(4)
		$\left(\frac{\sum_k s_{ik}^{TPP}\mu_k}{\sum_k s_{ik}^{2008}\mu_k}-1\right)$	$\left(\frac{u_i^{TPP}}{u_i^{2008}}-1\right)$	$\left(\frac{\omega^{TPP}}{\omega^{2008}}-1\right)$	$\left(\frac{\mathbb{W}^{TPP}}{\mathbb{W}^{2008}}-1\right)$
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
	Norway	0.002	0.097	-0.012	-0.108
	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
	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 (21) or (46); 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 (24). '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).

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 (21) or (49); 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 (24). 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).

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: 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.

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%.

Spatial Economics Research Centre (SERC)
London School of Economics
Houghton Street
London WC2A 2AE

Web: www.spatialeconomics.ac.uk