Trade and frictional unemployment in the global economy*

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Abstract

We develop a multi-country, multi-sector trade model with labor market frictions and equilibrium unemployment. Trade opening leads to a reduction in unemployment if it raises real wages and reallocates labor towards sectors with lower-than-average labor market frictions. We estimate sector-specific labor market frictions from 25 OECD countries and the trade parameters of the model using 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 sometimes work in opposite directions for some countries, 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.

Keywords: labor market frictions, unemployment, trade

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1 Introduction

We develop a multi-sector, multi-country general equilibrium trade model with labor market frictions and equilibrium unemployment. Our model emphasizes two channels whereby trade reforms such as preferential trade agreements affect the aggregate unemployment rate of a country: trade reforms reallocate resources across sectors and they affect overall job creation and real wages. 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 (and to a reduction in unemployment if it reallocates resources into sectors with lower-than-average labor market frictions). The *expansion* effect is a general equilibrium effect whereby a trade reform may spur aggregate job creation, which raises (real) wages and reduces unemployment in all sectors. Of course, if the trade reform under consideration discourages overall job creation in a country (as may happen in the presence of adverse terms-of-trade effects) then this general equilibrium effect is associated with an increase in its unemployment rate and a reduction its in real wages.

We then structurally estimate the parameters of the model using world trade data for over 130 countries and sectoral 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.[1] Equipped with this, we run a first counterfactual exercise, namely, we estimate the welfare and unemployment effects for all countries in our sample of eliminating trade barriers including all (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%; the net welfare effect is thus ambiguous *a priori*. We introduce a welfare criterion following Atkinson (1970) and Sen (1976) 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.

Designing a multi-country, multi-sector general equilibrium model of trade and equilibrium unemployment is important for several reasons. First, trade economists tend to insist on the real wage effects of trade, often dismissing its unemployment effects as of second-order importance, whereas policymakers and the public at large tend to voice concerns about, and support for trade agreements in terms of jobs gained or lost.[2] 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

[1] More precisely, we estimate one parameter per sector (μ), which is a combination of the sector-specific vacancy rate and of the sector-specific matching TFP. We refer to this parameter as the *matching efficiency* of the sector for short.

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

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.[3] 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. Any reform that raises aggregate demand boosts job creation, which raises wages and reduces unemployment (an *expansion effect*); thus, focusing on aggregate unemployment, as policymakers tend to do, or on real wages, as economists usually do, looks like looking at the same issue from two different angles. But this view misses the other half of the story whereby trade reforms reallocate resources such as labor across sectors. This *reallocation effect* has an impact on a country's unemployment rate because sectors have heterogeneous labor market frictions. We design an estimation strategy to measure these sector-specific labor market frictions in a theory-consistent way; 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 employment 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.[4] We complement such studies by looking at the effects of trade on frictional unemployment. Finally, our framework is quite flexible and the bulk 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 countries of the Asia Pacific region (as in the TPP agreement), and of removing trade imbalances in the spirit of Dekle, Eaton, and Kortum (2007).[5] Many others are possible.

The central quantitative 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 employment rates for which data is available. We also find that the global economic crisis that started in 2008 ended up having a proportional impact on unemployment rates across manufacturing sectors, which is consistent with our formulation of the labor market frictions as the product of country-time and sector-specific effects. A companion paper

[3]Other trade models with equilibrium unemployment include Brecher (1974), Davis (1998), Matusz (1986), Davidson, Martin, and Matusz (1998, 1999), Kreickemeier and Nelson (2006), Costinot (2009), Davis and Harrigan (2011), Helpman, Itskhoki and Redding (2010), Felbermayr, Prat, and Schmerer (2011), and Heid and Larch (2013).

[4]We account for the transition effects in our empirical framework using time dummies.

[5]There also exist several reports on the trade and unemployment effects of the TTIP. The Bertelsmann (2013) Report seems to be the most closely related to what we do in the present paper. See David Saha's 20 July 2014 blog on www.voxeu.org for a recent survey of such reports.

(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 (and conversely in countries whose comparative advantage is in sectors with low labor market frictions). This evidence is consistent with the *reallocation effect*.

The major normative contribution of the paper is to provide a rationale for the public's interest in employment effects of trade. In our model, all workers are *ex-ante* identical (recall that this is a Ricardian model) but some end up in involuntary unemployment. In addition, employed workers end up working in different sectors and earning different wages in equilibrium (though the *ex ante* expected wage is equalised across sectors). If society is averse to inequality (which can be the case even as workers are risk neutral), then we show that maximising a social welfare function as in Atkinson (1970) or Sen (1976) is conceptually similar to optimizing over a combination of the average real wage and the unemployment rate.[6] 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).

Ours is not the first paper to propose a trade model with labor market frictions (see footnote 3 above). Davidson, Martin, and Matusz (1986) and Helpman and Itskhoki (2010) feature Diamond-Mortensen-Pissarides labor market frictions. Davidson *et al.* embed labor market frictions into a Ricardian models of comparative advantage. Helpman and Itskhoki's model features intra-industry trade. We build on these by developing a multi-sector, multi-country trade model. The great advantage of such a contribution is threefold: we generalize the central theoretical predictions of two-country and/or two-sector trade models to a more realistic environment, we can structurally estimate its key parameters using trade and unemployment data, and we can use it to run counterfactual experiments.

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 lower 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.

[6]We also show that the planner cares only about average real wages in the limiting case of no inequality aversion (Bentham) and only about unemployment in the other limiting case of extreme inequality aversion (Rawls).

2 Technology and production

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

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

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

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

where the scale parameter $\varphi_{ik} > 0$ governs absolute productivity levels and the shape parameter $\theta > 1$ is negatively related to the scope for comparative advantage across varieties: the lower θ, the higher the dispersion of the φ_{ik}'s.[7]

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

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

[7] 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.

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:

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

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

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

Before proceeding, we want to emphasize that we assume below that labor market frictions are *sector*-specific. 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.[8] For the sake of simplicity, 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

[8] 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.

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 $\mathbb{U}_i$. For each worker actually hired, V_{ik}/H_{ik} vacancies need be open. Thus the per worker hiring cost is equal to $P_i \nu_{ik} V_{ik}/H_{ik}$. Using (6) and (7), this cost is equal to

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

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 sectoral labor market.

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 $E_{ik}(x) \equiv p_{ik}(x)\mathbb{Q}_{ik}(x)$ (E is a mnemonic for 'expenditure'). 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 variety x 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 look for a job and that this choice is irreversible.[9] 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.[10] 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 $w_i = P_i(\ell_{ik}/\mu_{ik})^{1/(1-\lambda)}$, for all k. Dividing both sides of this expression by P_i yields

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

[9] 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.

[10] 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.

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 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.[11] 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.[12] 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 $P_i = \gamma w_i \prod_k (\varphi_{ik}\ell_{ik})^{-\alpha_{ik}}$. 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 the efficiency of the labor matching functions (in addition to the TFP of the

[11] 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

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

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

[12] 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}, 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.

production functions). Another modification of the usual neoclassical framework is the power $1/\lambda$ at which productivity is being raised. This is because labor accounts for only a fraction of the matching function.

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

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

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 is not surprising 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 shiped from country i to country j reach their destination. We impose (i) $\tau_{iik} = 1$ for all sectors k, (ii) $\tau_{ijk} > 1$ for all (i, j, k) with $i \neq j$, and (iii) $\tau_{ilk} \leq \tau_{ijk}\tau_{jlk}$. Here, (i) is for convenience and we relax this assumption in our regressions and counterfactual exercises; (ii) states that trade across international borders is costlier than trade within countries; and (iii) 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 $c_i \equiv w_i^{\lambda} P_i^{1-\lambda}$ denote the 'input cost' in country i.[13] 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-like 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, sector k.

Inspection of (18) and (20) reveals that country i's volume of exports of good k to country j are not directly related to the size of the origin market while it is increasing in the destination market size,

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

$\alpha_{jk}E_j$. 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, country-sector-specific labor market matching efficiencies and country-sector-specific technologies have observationally identical effects on trade volumes. In other words, one cannot identify them separately by running a country-sector fixed effect regression on (20). Second, wages do not enter (18) linearly by $\lambda < 1$.

In the above, t_{ijk} contains c_i, which is endogenous. The model being block recursive, it is easy to show that the 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 Sections 6 and 7 by emphasizing the mechanisms at work in the model. We start with the consequences of marginal changes.

Marginal trade reforms. 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.[14] 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*. We use this terminology with caution here because this expression holds for *any* trade reform, including preferential trade liberalisations.

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 *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 sectors. 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 where trade gains are not redistributed through unemployment benefits, there are winners and losers in terms of employment.[15]

Substantial trade reforms. We now use (21) to compare two equilibriums – say, the actual equilibrium and a counterfactual one. 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

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

where

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

In the autarky allocation, $s_{ik}^{autarky} = \alpha_{ik}$ and $\operatorname{Cov}(\cdot) \equiv \sum_k \left(s_{ik} - \alpha_{ik}\right)\left(\mu_{ik} - \bar{\mu}_i\right)$ 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 $s_{ik} < \alpha_{ik}$

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

[15] 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.

holds in import-competing sectors. Of course, actual patterns of trade reflect not only technology-based source of comparative advantage but also heterogenous 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:

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

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

*(**ii**) The actual equilibrium employment rate in country i is greater than the counterfactual employment rate 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:*

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

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 Ricardian 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:

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

where $\zeta, \xi > 0$ are parameters. 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 $\zeta \to 0$, society is so inequality-averse that it only 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 $\zeta = \xi = 1$, so that

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

In Appendix A, we show that this criterion is a reasonable approximation in our context of both Atkinson's (1970) and Sen's (1976) popular social welfare functions.

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

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 improved 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. 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 counterfactuals 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 from the ILO Key Indicators of the labor Market (KILM) database, while the trade balance for year 2008 is sourced from World Bank Development Indicators (WDI) database.

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

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 labor market frictions are not a source of Ricardian comparative advantage and, allowing for the time dimension, we henceforth 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 than countries with more rigid rules. This specification also allows for country-specific business cycles. Finally, job creation and the matching of workers and firms is easier in sectors with high a μ_k than in sectors with a low μ_k across countries and time.

We can now estimate the μ_k's in a structural way as follows. Rewriting, taking logs of (13) and allowing for time variation yields

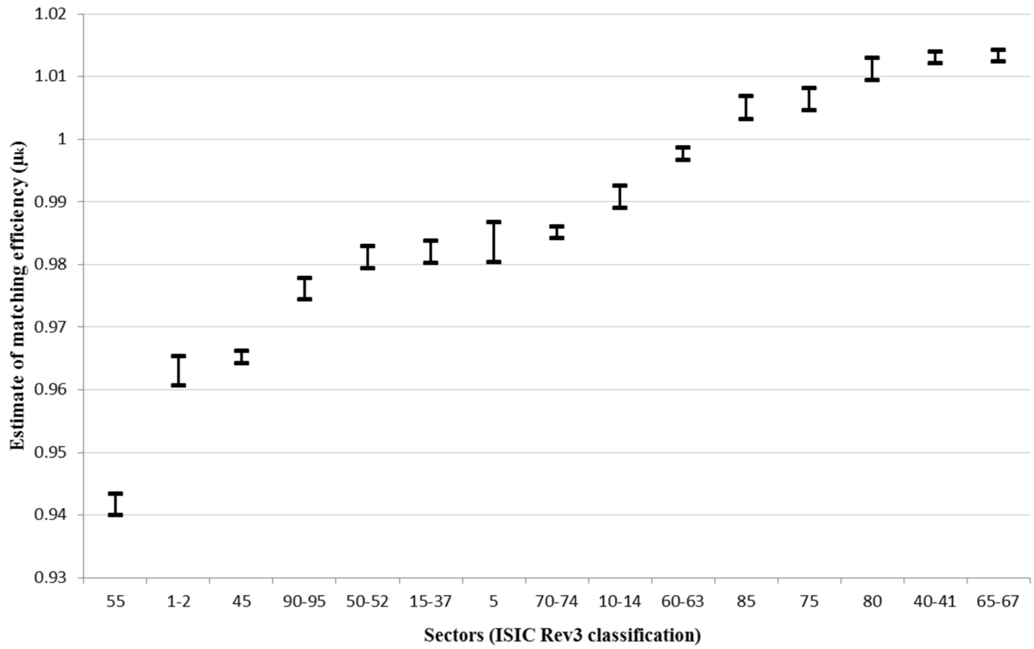
$$\ln \ell_{ikt} = \ln \left(\mu_{it}\omega_{it}^{1-\lambda}\right) + \ln \mu_k,$$

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

We use sectoral unemployment data for 25 OECD countries for the period 2001-2008, sourced from the KILM database. Sectoral unemployment data is available for 15 aggregate sectors (see list in Table 1), of which one aggregate sector is the manufacturing sector.

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

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



As we are particularly interested in estimating relative matching efficiencies of different manufacturing sectors, we proceed to extract 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.'

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. Such data are provided for the US by the Bureau of Labor Statistics. We expect 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

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

		(1)	(2)
ISICRev3	Sector description	μ_k	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).

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.

These are reassuring on three counts. First, the correlations are strong (0.7 on average). Second, all correlations are between a US variable and an OECD average variable, which 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 remains the same as in the previous years in a statistical sense.

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 shows correlation and Spearman correlation between estimated matching efficiencies 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.

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

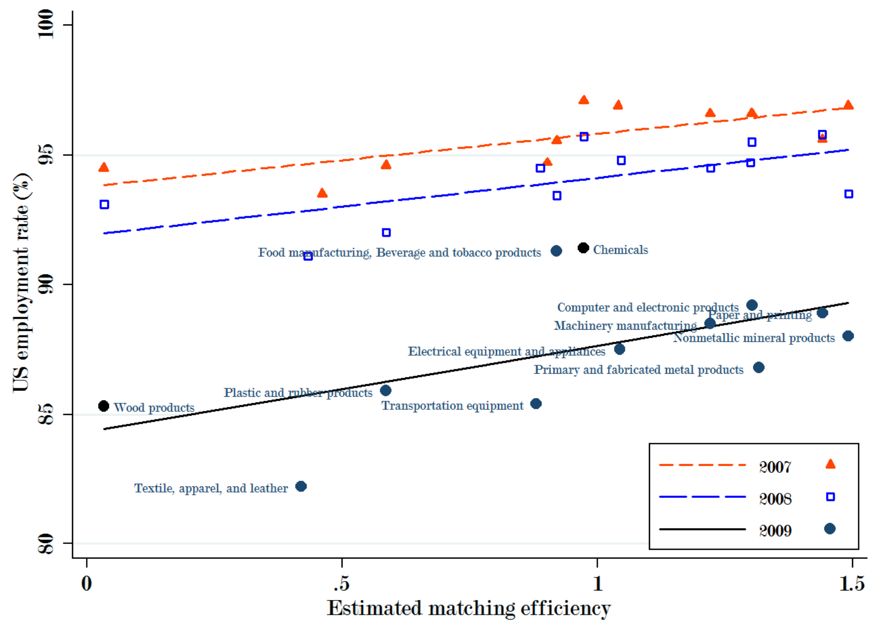
$$\ln E_{ijk} = -\theta \ln \tau_{ijk} - \theta \ln \kappa_{ik} - \ln \sum_{i'=1}^{I} (\tau_{i'jk}\kappa_{i'k})^{-\theta} + \ln(\alpha_{jk}E_j), \tag{25}$$

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

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

captures exporter-sector unobservables.

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 estimated matching efficiencies 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.

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 (2015) and the estimates of Simonovska and Waugh (2014).[16]

7 Unemployment and welfare effects under various scenarios

In this section we compute a series of counterfactual exercises. Subsections 7.1, 7.2, and 7.5 describe the methodology, while subsections 7.3, 7.4, and 7.6 report the counterfactual real wage, welfare, and unemployment effects of the Transatlantic Trade and Investment Partnership (TTIP), of the Trans Pacific Partnership (TPP), and of balancing trade in all countries, respectively. We set the matching elasticity at $\lambda = 0.6$ throughout. This is the midpoint of the 'plausible range' $[0.5 - 0.7]$ in Petrongolo and Pissarides (2001). We run sensitivity tests in Appendix D. The reader interested in the counterfactual figures only can skip the methodology subsections 7.1, 7.2, and 7.5.

As we shall see, under both the TTIP and the TPP scenarios, participating countries *usually* experience a real wage increase and a fall in the unemployment rate while excluded OECD countries *usually* experience a fall in real wages and a rise in unemployment. For countries that do fit such sharp patterns, the welfare effects (which combine the real wage and the unemployment effects) are unambiguous. We write 'usually' because the reallocation effect affects both groups of countries in a heterogeneous fashion and, as a result, some countries get an adverse unemployment effect even though their real wage increases (and vice-versa).

Under the trade balance scenario, all deficit countries are made worse off and most surplus countries are made better off. Unlike in the previous two scenarios, the unemployment, real wage, and welfare effects are substantial (Norway would benefit enormously, Greece would be hit badly). This was to be expected because trade imbalances are much more important than the remaining trade barriers among OECD countries.

7.1 Counterfactual trade flows and production shares

The aim of this subsection is to compute the counterfactual changes of real wages, unemployment rates and welfare for two FTA scenarios under the assumption that tariffs (as well as some non-tariff barriers) in agriculture and manufactures are eliminated between all members of a given FTA. To this aim, we need to compute the counterfactual fraction of workers allocated to each sector in any arbitrary

[16] The median and the mean coefficients of 744 statistically significant estimates (obtained from 32 papers) of the price elasticity in gravity regardless of the method are equal to -3.19 and -4.51, respectively (Head and Mayer, 2015). 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).

country, E_{ik}/E_i, and the counterfactual wage and price levels, w_i and p_i, *taking account of general equilibrium effects.* Including general equilibrium implies, in particular, that we ought to allow the vector of exporter-sector unobservables, κ_{ik}^{FTA}, to change with the policy experiment.

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

$$\text{tariff}_{ijk}^{FTA} = \begin{cases} 0 & \text{if} \quad i,j \in \{\text{FTA member}\} \\ t_{ijk} & \text{otherwise} \end{cases}$$

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,

$$ED_i \equiv \sum_{j=1}^{J} \sum_{k=1}^{K} \left(\frac{\hat{t}_{ijk}}{\hat{T}_{jk}} \right)^{-\theta} \alpha_k E_j - E_i, \tag{28}$$

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 $t_{ijk}/T_{jk} = 0$ 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 $\mathbf{E} \equiv \begin{bmatrix} E_1 & ... & E_I \end{bmatrix}'$ 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'.[17] 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).

[17] We may rewrite (28) 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.

(iii) Trade balances in the FTA equilibrium if

$$ED_i^{FTA} \equiv \sum_{j=1}^{J}\sum_{k=1}^{K}\left(\frac{t_{ijk}^{FTA}}{T_{jk}^{FTA}}\right)^{-\theta}\alpha_k E_j^{FTA} - E_i^{FTA} \tag{29}$$

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,

$$\tilde{\tau}_{ijk} = \begin{cases} \frac{1}{1+\text{tariff}_{ijk}} e^{\hat{\delta}_{rta}} & \text{if} \quad i,j \in \{\text{FTA member}\} \\ 1 & \text{otherwise.} \end{cases} \tag{30}$$

Using these relationships, we rewrite (29) as

$$ED_i^{FTA} \equiv \sum_{j=1}^{J}\sum_{k=1}^{K}\left(\frac{\hat{t}_{ijk}\tilde{\tau}_{ijk}\tilde{\kappa}_i}{\sum_{i'}\hat{t}_{i'jk}\tilde{\tau}_{i'jk}\tilde{\kappa}_{i'}}\right)^{-\theta}\alpha_k E_j^C\tilde{E}_j - E_i^C\tilde{E}_i, \tag{31}$$

where the $\hat{t}_{ijk}$'s are the same as in (28) and the E_i^C's are the excess-demand minimizing E_i's of (28). 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

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

In the trade equilibrium, the price index is equal to $P_i = \gamma\prod_k\left[\sum_j(\tau_{jik}\kappa_{ik})^{-\theta}\right]^{-\alpha_k/\theta}$. Using the tilde notation for prices as well as (30), 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 (29), and

$$e\tilde{\kappa}_i \equiv \tilde{E}_i^{\hat{\lambda}}\tilde{P}_i^{1-\hat{\lambda}} - \tilde{\kappa}_i = \tilde{E}_i^{\hat{\lambda}}\prod_{k=1}^{K}\left[\frac{\sum_{j=1}^{J}\left(\hat{\tau}_{ijk}\hat{\kappa}_{jk}\tilde{\tau}_{ijk}\tilde{\kappa}_j\right)^{-\theta}}{\sum_{j=1}^{J}\left(\hat{\tau}_{ijk}\hat{\kappa}_{jk}\right)^{-\theta}}\right]^{-\frac{\alpha_k}{\theta}(1-\hat{\lambda})} - \tilde{\kappa}_i, \tag{32}$$

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 (31) and of $e\tilde{\kappa}_i$ in (32). This being a high-dimensional non-linear system, we do this by iterations using Matlab.

7.2 Counterfactual labor shares and unemployment rates

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 (30) and the estimated ratios $\tilde{\mathbf{E}}$ and $\tilde{\kappa}$:

$$\tilde{E}_{ijk} = \begin{cases} \tilde{\tau}_{ijk}^{-\hat{\theta}} \tilde{\kappa}_i^{-\hat{\theta}} \frac{\sum_{i'=1}^{I} \left[\hat{\tau}_{i'jk} \hat{\kappa}_{i'k}\right]^{-\hat{\theta}}}{\sum_{i'=1}^{I} \left[\hat{\tau}_{i'jk} \hat{\kappa}_{i'k} \tilde{\tau}_{i'jk} \tilde{\kappa}_{i'}\right]^{-\hat{\theta}}} \tilde{E}_j & \text{if} \quad k \in \mathbb{K}_T \\ \tilde{E}_i & \text{if} \quad k \in \mathbb{K}_N \quad \text{and} \quad j = i \\ 0 & \text{if} \quad k \in \mathbb{K}_N \quad \text{and} \quad j \neq i \end{cases} \tag{33}$$

The simplicity of this expression for $k \in \mathbb{K}_N$ arises because domestic production is proportional to domestic income by Cobb-Douglas preferences for non tradable goods.

The counterfactual FTA labor shares are equal to

$$s_{ik}^{FTA} = \frac{\sum_{j=1}^{J} E_{ijk} \tilde{E}_{ijk}}{\sum_{k'=1}^{K} \sum_{j=1}^{J} E_{ijk'} \tilde{E}_{ijk'}}, \tag{34}$$

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

$$\frac{\ell_i^{FTA}}{\ell_i} = \left(\frac{\tilde{E}_i}{\tilde{P}_i}\right)^{1-\lambda} \frac{\sum_k s_{ik}^{FTA} \mu_k}{\sum_k s_{ik} \mu_k}. \tag{35}$$

7.3 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 (tariffs, unnecessary regulations, restrictions on investment etc.). 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 notwithstanding job creation, trade agreements can lead to higher unemployment if workers are reallocated into sectors with higher-than-average labor market frictions.

In this counterfactual exercise, we set all bilateral EU-US tariffs to zero and we turn 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.[18] All values are in %.

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

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 members	Austria	3.8	0.021	-1.421	0.087	1.531
	Belgium	7.0	-0.057	0.713	0.010	-0.699
	Czech Rep.	4.4	-0.007	-1.014	0.133	1.159
	Denmark	3.4	0.017	-1.430	0.082	1.534
	Estonia	5.5	-0.023	-1.293	0.247	1.560
	Finland	6.3	-0.024	-1.267	0.275	1.562
	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	1.690
	Hungary	7.8	0.037	-1.235	0.168	1.420
	Ireland	4.6	-0.260	3.133	0.272	-2.774
	Italy	6.7	-0.034	0.197	0.050	-0.146
	Netherlands	2.8	-0.035	1.103	0.008	-1.083
	Poland	7.1	0.003	-0.821	0.150	0.979
	Portugal	7.7	0.006	-1.560	0.311	1.900
	Slovenia	4.4	-0.021	-1.235	0.195	1.448
	Spain	8.4	-0.062	-1.946	0.604	2.600
	Sweden	6.3	0.002	-1.335	0.220	1.576
	United Kingdom	5.4	-0.021	-1.492	0.266	1.784
EU-19	**Average**	**6.7**	**-0.025**	**-0.557**	**0.168**	**0.208**
	United States	**5.9**	**-0.172**	**1.100**	**0.259**	**-0.832**
Other OECD	Canada	6.3	-0.008	1.011	-0.150	-1.149
	Iceland	3.0	0.027	-0.214	-0.050	0.164
	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	-1.399
	New Zealand	3.9	0.009	-0.209	-0.001	0.209
	Norway	2.6	0.005	0.413	-0.039	-0.450
	Switzerland	3.4	0.029	-0.689	-0.013	0.681

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 equation (21). 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).

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' ($\frac{\omega_i^{FTA}}{\omega_i^{2008}} = \frac{\tilde{E}_i}{\tilde{P}_i}$). Finally, column five reports changes in welfare as measured by (24): it is approximately equal to the difference between columns 4 and 3. The top panel of Table 4 reports results for potential members of the TTIP (US and EU countries); the bottom panel reports results for a subset of OECD countries left out of the agreement.

The first thing to observe from the table is that the magnitude of the predicted changes is small. One reason for this is because EU-US tariffs are already low to start with; the other reason for this finding 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 2015).[19] We also include non-traded goods, which tends to reduce estimates further.

Next, all countries signing the agreement gain in terms of increased real wages. By contrast, the effect on country-wide employment is highly heterogeneous, both in direction and magnitude. Unemployment in the US is predicted to rise by 1.1% from a rate of 5.9% in the baseline year 2008, but it 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 in real wages due to increased production and reduced import prices, it may also lead to a restructuring of production and consequent reallocation of workers across sectors. Insofar as these 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 would experience an increase in their long-term unemployment rate under TTIP. This seems to be the case for countries such as Belgium, Italy, and the Netherlands. For all these countries, there are gains from trade in terms of an increase in the real wage, but welfare is predicted to fall due to an increase in unemployment. In the German case, the unemployment and the real wage effects exactly cancel out.

The real wage and unemployment effects are similarly diverse for countries that are excluded from the TTIP and as such suffer from trade diversion. Also, while most of these countries are predicted to experience a decline in real wages, some such as Switzerland, New Zealand, and Island do experience a reduction in unemployment and an increase in welfare according to our synthetic criterion (24).

[19] 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 (2015) simulate the welfare effect of an unilateral US 40% tariff assuming that all tariffs are zero in the initial equilibrium. They find an average world welfare effect of -0.2% in the one sector framework and -0.14% when allowing for multiple sectors.

7.4 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) currently being touted among 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.

Observe first that the magnitude of the effects is smaller than under the TTIP. This was to be expected, for distance-related trade barriers remain a surprisingly substantial impediment to trade (Disdier and Head, 2008; Head and Mayer, 2015) and the area of the Pacific Ocean is about 55% larger than the area of the Atlantic Ocean. Specifically, the US would benefit less from the TPP than from the TTIP but the real wage and welfare effects are small in both cases. The employment effect is positive under TTIP and slightly negative under TPP.

Next, all potential members would experience a real wage increase (column 4, top panel) and decreasing but virtually unchanged real wages for excluded countries (column 4, bottom panel). The reallocation effect is heterogeneous for both groups of countries (column 2); this pattern is similar to the corresponding pattern of subsection 7.3. Unemployment is predicted to fall in all participating countries and to increase slightly in non-participating countries (column 3). As a result, the welfare effects of column 5 are unambiguously positive for participating countries and negative for the non-participating ones.

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, EU countries are usually made slightly worse-off under TPP (while most are better-off under TTIP), relative to the status quo.

7.5 Counterfactual allocation under balanced trade

At no point in time is trade balanced in any country (Dekle, Eaton, and Kortum 2007). Our aim here is to estimate the unemployment and welfare effects of eliminating trade imbalances. This subsection describes the estimation procedure; subsection 7.6 reports and discusses the results.

The estimation procedure of Subsections 7.1 and 7.2 remain valid, with the exception that under the trade balance scenario (henceforth TB) 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 (28)

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	4.731
	Japan	0.133	-4.684	0.155	5.077
	Mexico	0.001	-2.344	0.211	2.616
	New Zealand	-0.241	-5.247	1.142	6.743
	United States	-0.006	-0.248	0.053	0.302
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	-0.033
	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**	**-0.014**
Other OECD	Iceland	0.010	0.424	-0.059	-0.481
	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 equation (21); 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).

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 Subsection 7.1, 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, in particular, $\tilde{\tau}_{ijk} = 1$ for all i, j, k. The excess demand system in this counterfactual world is isomorphic to (31):

$$ED_i^{TB} \equiv \sum_{j=1}^{J} \sum_{k=1}^{K} \left(\frac{\hat{t}_{ijk} \tilde{\kappa}_i}{\sum_{i'} \hat{t}_{i'jk} \tilde{\kappa}_{i'}} \right)^{-\theta} \alpha_k E_j^{TB} \tilde{E}_j - E_i^{TB} \tilde{E}_i. \tag{36}$$

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

$$e\tilde{\kappa}_i = \tilde{E}_i^{\hat{\lambda}} \prod_{k=1}^{K} \left[\frac{\sum_{j=1}^{J} \left(\hat{\tau}_{ijk} \hat{\kappa}_{jk} \tilde{\kappa}_j \right)^{-\theta}}{\sum_{j=1}^{J} \left(\hat{\tau}_{ijk} \hat{\kappa}_{jk} \right)^{-\theta}} \right]^{-\frac{\alpha_k}{\theta}(1-\hat{\lambda})} - \tilde{\kappa}_i. \tag{37}$$

We solve for the vectors $\mathbf{E}$ and $\tilde{\kappa}$ that jointly minimize the sums of squares in (36) and (37).

Finally, we compute the counterfactual (balanced trade) trade flows, labor shares, and the employment rates as in (33), (34), and

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

respectively.

7.6 The trade balance scenario

We set the trade balance of all countries in our database to zero. Table 6 reports the results. Several features 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 -2.7% 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 (deficit) OECD so that eliminating trade deficits requires larger corrections than eliminating current account deficits.

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	-1.46
	Canada	0.972	0.00	-8.24	1.23	10.33
	Czech Rep.	0.999	0.14	2.90	-0.62	-3.42
	Denmark	0.997	0.05	4.45	-0.47	-4.71
	Finland	0.932	0.02	-9.62	1.40	12.19
	Germany	0.927	-0.49	-2.71	1.59	4.42
	Ireland	0.834	-1.28	-17.78	4.88	27.55
	Japan	0.989	-0.19	1.77	0.25	-1.50
	Netherlands	0.938	0.06	-20.15	1.15	26.69
	Norway	0.813	-0.12	-70.94	4.53	259.71
	Sweden	0.946	0.01	-6.87	1.01	8.47
	Switzerland	0.951	0.11	-13.56	0.81	16.62
$b > 1$	Belgium	1.027	0.09	6.47	-1.27	-7.27
	Estonia	1.116	-0.40	47.84	-5.25	-35.91
	France	1.026	0.08	5.44	-1.15	-6.25
	Greece	1.183	-0.15	46.65	-8.13	-37.35
	Hungary	1.009	0.17	1.50	-0.66	-2.13
	Iceland	1.056	0.76	23.44	-3.24	-21.61
	Israel	1.030	-0.11	8.83	-1.04	-9.07
	Italy	1.001	0.13	-1.07	-0.11	0.98
	Mexico	1.016	0.11	3.09	-0.49	-3.48
	New Zealand	1.016	-0.14	10.57	-0.64	-10.14
	Poland	1.058	0.28	12.98	-2.80	-13.96
	Portugal	1.129	0.12	26.09	-5.03	-24.68
	Slovenia	1.050	0.51	10.13	-2.15	-11.15
	Spain	1.078	0.72	4.07	-2.39	-6.21
	United Kingdom	1.062	0.46	6.89	-1.89	-8.21
	United States	1.057	0.00	1.92	-0.27	-2.15
EU-19	**Avg.**	**1.014**	**0.10**	**3.64**	**-0.90**	**-1.54**
Sample	**Avg.**	**1.021**	**0.03**	**2.09**	**-0.43**	**-0.87**

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 equation (35); 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).

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 employment contracts. 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, Finland, and Japan – are made worse off.

Finally, the magnitude of the effects here are much larger than that of creating free trade areas (for instance, Norway is predicted to experience a drop of 70 % in its unemployment rate, which on its own accounts for the almost three-fold increase in its welfare). 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) while remaining trade frictions in OECD countries are small.

8 Conclusion

This paper has introduced a multi-country, multi-sector general equilibrium model with international trade and labor market matching frictions. The equilibrium frictional unemployment rate of each country depends on the patterns of trade. The model features an expansion effect: when trade openness is associated with higher real wages, as is the case if the terms-of-trade effects are non-negative, then such gains translate into more job openings and lower equilibrium unemployment rates. The model also features a reallocation effect: ceteris paribus, the unemployment rate increases if the trade reform achieves a reallocation of resources towards labor market friction-intensive sectors, and conversely if sectors with relatively high labor market frictions contract and sectors with relatively high matching efficiency expand following this trade reform. A companion paper (Carrère et al. 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 a welfare criterion based on Atkinson (1970) and 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 under negotiation, 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; Ossa, 2012). In ongoing work, we are allowing for the scope of comparative advantage (and thus the elasticity of trade values with respect to trade costs θ) to vary across sectors, as in Ossa (2012). We thus expect our real wage effects to be higher on average under this alternative specification.

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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 market 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

$$c_{is} \equiv P_i \left(\frac{\ell_{is}^{\lambda}}{\mu_{is}} \right)^{\frac{1}{1-\lambda}} \tag{38}$$

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:

$$w_{iks}(x) = w_{is} = c_{is}. \tag{39}$$

Labor market

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

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

$$w_i = \ell_{is} w_{is}. \tag{40}$$

Combining this expression with (38) and (39) yields:

$$\frac{w_i}{P_i} = \left(\frac{\ell_{is}}{\mu_{is}}\right)^{\frac{1}{1-\lambda}}. \tag{41}$$

This implies that occupations with high matching efficiency μ_{is} have higher employment rate and, by the no-arbitrage condition (40), lower wages.

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

$$\forall s, \tilde{s} : \frac{H_{iks}}{H_{ik\tilde{s}}} = \frac{a_{ks}}{a_{k\tilde{s}}}\frac{\mu_{is}}{\mu_{i\tilde{s}}}. \tag{42}$$

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 (42). Specifically:

$$h_{iks} \equiv \frac{H_{iks}}{\sum_{\tilde{s}} H_{ik\tilde{s}}} = \frac{\mu_{is} a_{ks}}{\sum_{\tilde{s}} \mu_{i\tilde{s}} a_{k\tilde{s}}} \tag{43}$$

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:

$$s_{iks} \equiv \frac{L_{iks}}{\sum_{\tilde{s}} L_{ik\tilde{s}}} = a_{ks}. \tag{44}$$

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 (41) and (44) that the average employment rate in a sector k is equal to:

$$\begin{aligned}\bar{\ell}_{ik} \equiv \sum_{s=1}^{S} s_{iks}\ell_{is} &= \left(\frac{w_i}{P_i}\right)^{1-\lambda} \sum_{s=1}^{S} a_{ks}\mu_{is} \\ &= \left(\frac{w_i}{P_i}\right)^{1-\lambda} \bar{\mu}_{ik}, \end{aligned} \tag{45}$$

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 (38), (39) and (43):

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

Combining with (45) 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

Here we show how (24) is an approximation of criteria developed by Atkinson (1970) and Sen (1976). Let $b\omega$ define the real unemployment benefit granted to the unemployed, expressed here as a fraction $b \in (0,1)$ of the average real wage ω. In our model, b is normalized to zero.

We consider two welfare criteria to compare a counterfactual situation with the current allocation. The first welfare criterion, due to Atkinson (1970) as extended by Fleurbaey and Hammond (2004), can be written as a generalized average of individual (real) wages:

$$\mathbb{W}(\eta) \equiv \left[\sum_{k=1}^{K} s_k \ell_k \omega_k^{1-\eta} + u(b\omega)^{1-\eta} \right]^{\frac{1}{1-\eta}}, \tag{46}$$

where η is the *relative rate of inequality aversion*; $\eta = 0$ for Bentham and $\eta = +\infty$ for Rawls.[20] 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 (46) 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. We pick this particular value because it has empirical support.[21] This value for η yields

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

as in (24).

An alternative welfare criterion that we may use was proposed by Sen (1976). Let

$$\mathbb{W} = \omega(1 - \mathbb{G}), \tag{47}$$

where $\mathbb{G}$ is the Gini coefficient of earnings inequality. This criterion satisfies several desirable properties.[22] Like in (46), $\mathbb{W}$ is increasing in average real wages and decreasing in real wage dispersion. If $b = 0$ 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

[20] For $\eta = 1$, $\mathbb{W}$ is equal to $\exp\{\sum s_k \ell_k \ln \omega_k + u(\ln b + \ln \omega)\}$.

[21] 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.

[22] 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.

rate u. Since our focus is on the unemployment rate, we disregard within-worker wage heterogeneity and use $\mathbb{G} \approx u$ so that (47) implies

$$\frac{\mathbb{W}^{CF}}{\mathbb{W}} = \frac{\omega^{CF}\left(1 - u^{CF}\right)}{\omega(1-u)} \equiv \frac{\omega^{CF}\ell^{CF}}{\omega\ell}. \tag{48}$$

If $u = \ell = 1/2$ then $\hat{u} + \hat{\ell} = 0$ and, for marginal changes of u, the criteria in (24) and (48) 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 (48).

In the text, we have chosen to report only one value for welfare changes in order to keep the analysis focused. Our choice of Atkinson's over Sen's criterion is somewhat arbitrary.

Appendix C: Gravity estimation results

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.

Appendix D: Unemployment and welfare results for different values of matching elasticity (λ)

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

	TTIP				**TPP**				**TB**			
	$\left(\frac{u_i^{TTIP}}{u_i^{2008}}-1\right)$		$\left(\frac{W^{TTIP}}{W^{2008}}-1\right)$		$\left(\frac{u_i^{TPP}}{u_i^{2008}}-1\right)$		$\left(\frac{W^{TPP}}{W^{2008}}-1\right)$		$\left(\frac{u_i^{TB}}{u_i^{2008}}-1\right)$		$\left(\frac{W^{TB}}{W^{2008}}-1\right)$	
$\lambda = \rightarrow$	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	0.143	0.090	0.18	0.08	-0.018	-0.015	9.00	-2.13	-0.217	-0.017
BEL	0.57	0.75	-0.101	-0.106	0.00	0.02	-0.007	-0.006	21.12	-0.01	-2.091	-1.338
CAN	2.47	0.28	-0.210	-0.121	-12.48	-0.68	1.040	0.648	-22.84	-1.26	2.137	1.388
CHE	-0.40	-0.82	0.037	0.045	-0.01	0.07	-0.013	-0.012	-34.04	-4.75	2.223	1.730
CZE	-3.79	-0.05	0.208	0.128	0.16	0.03	-0.015	-0.011	14.94	-2.20	-0.972	-0.604
DEU	-0.25	0.11	-0.027	-0.040	0.00	-0.02	-0.011	-0.010	-20.34	4.77	3.843	2.865
DNK	-3.73	-0.65	0.108	0.058	0.05	0.04	-0.011	-0.009	16.37	-0.70	-0.730	-0.451
ESP	-8.38	0.25	1.160	0.795	0.09	0.02	-0.018	-0.014	28.61	-6.10	-5.487	-4.105
EST	-5.34	0.12	0.395	0.247	0.09	0.06	-0.011	-0.008	122.53	12.89	-12.142	-9.252
FIN	-5.11	0.09	0.424	0.259	0.18	0.04	-0.026	-0.019	-27.44	-1.75	3.265	2.410
FRA	-1.15	0.44	0.081	0.022	0.07	0.04	-0.013	-0.011	18.65	-0.11	-2.250	-1.571
GBR	-6.05	0.06	0.465	0.306	0.09	0.00	-0.014	-0.011	37.59	-5.96	-4.198	-3.098
GRC	-4.45	-0.29	0.490	0.323	0.21	0.04	-0.033	-0.023	132.22	8.55	-16.634	-12.283
HUN	-3.14	-0.57	0.293	0.192	0.09	-0.01	-0.019	-0.014	9.71	-1.54	-1.268	-0.873
IRL	-2.34	5.01	0.243	0.079	-0.03	-0.20	-0.003	0.001	-100.00	20.46	8.711	5.648
ISL	1.04	-0.76	-0.055	-0.024	1.82	-0.19	-0.098	-0.062	111.50	-17.07	-5.545	-3.661
ISR	0.21	0.01	-0.008	-0.001	0.11	0.03	-0.011	-0.007	24.74	2.68	-2.401	-1.788
ITA	-0.50	0.43	-0.008	-0.038	0.04	0.01	-0.013	-0.011	0.51	-1.66	0.067	0.133
JPN	0.10	0.13	0.009	0.008	-8.84	-3.35	0.265	0.172	-4.08	4.07	0.852	0.699
MEX	2.45	0.89	0.001	0.033	-8.18	-0.40	0.370	0.243	16.94	-2.20	-1.091	-0.799
NLD	0.82	1.19	-0.070	-0.075	0.06	0.11	-0.010	-0.010	-57.26	-4.82	3.103	2.396
NOR	1.47	-0.07	-0.064	-0.041	0.36	-0.05	-0.025	-0.018	-100.00	-6.90	9.063	6.201
NZL	-0.14	-0.23	0.015	0.015	-33.36	4.13	1.994	1.302	25.00	4.48	-1.916	-1.538
POL	-2.68	-0.17	0.261	0.171	0.12	0.04	-0.020	-0.016	45.12	-1.26	-5.548	-3.927
PRT	-5.21	-0.32	0.562	0.375	0.16	0.10	-0.029	-0.025	80.85	2.69	-13.313	-10.586
SVN	-5.24	0.18	0.308	0.191	0.20	0.03	-0.019	-0.014	52.52	-8.03	-4.176	-2.919
SWE	-4.51	-0.24	0.378	0.246	0.15	0.01	-0.027	-0.021	-20.01	-1.17	2.475	1.858
USA	-2.94	2.48	0.476	0.320	-1.24	-0.03	0.074	0.042	5.80	0.26	-1.065	-0.904

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%.