Trade Liberalization, an Employment Double-Dividend Hypothesis, and Welfare with Heterogeneous Firms

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Abstract

Can trade liberalization deliver an employment double dividend and a welfare gain? To answer this question, we develop a trade model with firm heterogeneity, search and matching frictions, and an emissions tax. We first analytically decompose the impact of trade liberalization on the amount of emissions into four forces: an increase in labor supply that leads to the larger amount of emissions; an increase in output per firm that may lead to the larger or smaller amount of emissions depending on how competitive markets are; a rise in a cutoff productivity that leads to the larger amount of emissions; and an increase in output per firm independent of market competitiveness that leads to the larger amount of emissions. When the second force dominates the others and markets are competitive enough, trade liberalization may support an employment double-dividend hypothesis, or otherwise it rejects the hypothesis. Moreover, due to these four counteracting forces, trade liberalization may deliver a welfare loss. We then simulate our model to better understand an interaction between trade liberalization, environmental regulations, and welfare. For the typical parameter values used in the literature, an employment double-dividend hypothesis is rejected. A deliberate investment in abatement technology, however, enables an economy to transit from a dirty equilibrium with higher unemployment to a clean equilibrium with lower unemployment.

Keywords: Trade Liberalization; Employment Double Dividend; Firm Heterogeneity; Welfare
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1. Introduction

Can trade liberalization deliver an employment double dividend and a welfare gain? Or can it *jointly* lower the rate of unemployment and improve environmental quality with welfare

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improved? To answer this question, we develop a trade model with firm heterogeneity, search and matching frictions, and an emissions tax. We first analytically decompose the impact of trade liberalization on the amount of emissions into *four* forces: an increase in labor supply that leads to the larger amount of emissions; an increase in output per firm that may lead to the larger or smaller amount of emissions depending on how competitive markets are; a rise in a cutoff productivity that leads to the larger amount of emissions; and an increase in output per firm independent of market competitiveness that leads to the larger amount of emissions. We show that when markets are less competitive, an employment double-dividend hypothesis is *rejected*. In contrast, when they are competitive enough, the hypothesis may *hold* if the second force responds to trade liberalization more strongly than the other forces. Moreover, due to these four counteracting forces, trade liberalization may deliver a welfare *loss*.

We then simulate our model to better understand an interaction between trade liberalization, environmental regulations, and welfare. Our baseline simulation shows that trade liberalization delivers a welfare *loss* in an economy with *weaker* environmental regulations, whereas it delivers a welfare *gain* in an economy with *stronger* environmental regulations or in an economy that has invested enough in abatement technology. An employment double-dividend hypothesis is rejected for the typical parameter values used in the literature: an economy is likely to face a trade-off between the rate of unemployment and environmental quality. A deliberate investment in abatement technology, however, enables an economy to transit from a dirty equilibrium with higher unemployment to a clean equilibrium with lower unemployment. Thus, our overall results suggest that a country paying little attention to the environment is more likely to suffer from *higher* unemployment and the *larger* amount of emissions, and is *less* likely to benefit from trade liberalization.

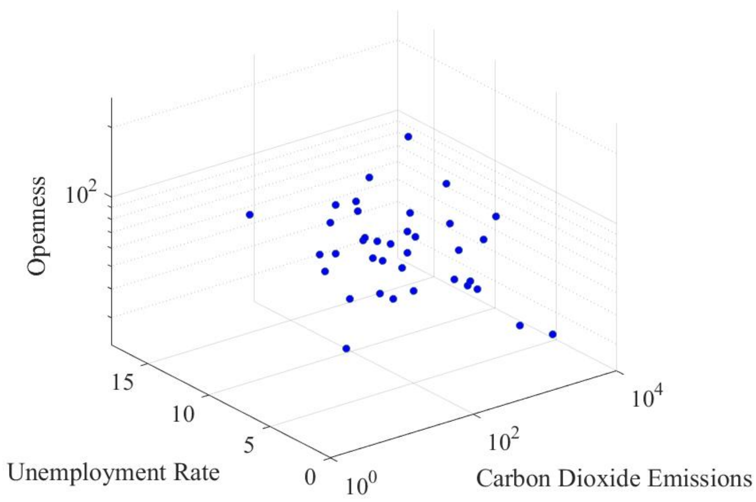

Figure 1: Unemployment rate, carbon dioxide emissions, and openness among 37 OECD countries in 2019. Carbon dioxide emissions (in megatons) and openness are scaled logarithmically. Source: Unemployment rate is from IMF World Economic Outlook Database (October, 2020), carbon dioxide emissions from the Global Carbon Budget 2020, and openness from Penn World Table 10.0.

Figure 1 shows an interaction between unemployment rate, carbon dioxide emissions, and openness among 37 OECD countries in 2019. As we can see, countries differ substantially according to their *openness*—defined as the sum of exports and imports of goods and services relative to GDP. A look at only the link between unemployment rate and the amount of emissions, therefore, leads to the inaccurate understanding of their relationship. Nonetheless, studies on an employment double-dividend hypothesis have ignored the role of openness in their analysis.[1] For example, assuming a *closed* economy, the earlier theoretical papers such as Bovenberg and de Mooij (1994) and Fullerton (1997) and a recent paper such as Wang and Ouattara (2020) reject an employment double-dividend hypothesis.[2]

There are some papers that assume a small open economy (but *lacks* the measure of openness). Bovenberg and van der Ploeg (1998) construct a model in which the wage is exogenously rigid and support the hypothesis. Holmlund and Kolm (2000) develop a search and matching model without a job creation condition in which an economy consists of tradable and non-tradable sectors. They show that an increase in emissions taxes leads to a decrease in employment in the former sector, whereas an increase in employment in the latter sector. As a result, depending on the wage premium of workers in two sectors, the hypothesis can hold or can be rejected. Chao and Yu (2003) reject the hypothesis by constructing a Harris-Todaro model with urban unemployment and the exogenously and downwardly rigid wage. In this way, theoretical studies so far have provided a mixed insight into an employment double-dividend hypothesis.[3] Thus, as Figure 1 suggests, we develop an open-economy model that can explicitly capture the international variation in *openness*.

To this end, we extend the model of Felbermayr et al. (2011) that has first integrated a search and matching model of Pissarides (2000) into a trade model with heterogeneous firms of Melitz (2003) by introducing emissions. Not only do we introduce the environment but we also remedy two shortcomings of Felbermayr et al. (2011). First, though they derive equilibrium values of aggregate variables, analytical comparative statics is latent. As we show in Section 3, through changes in the total mass of firms, trade liberalization and an environmental policy have much more profound implications than their original results.

[1]We follow Carraro et al. (1996) and define an *employment double dividend* as a decrease in the rate of unemployment *and* better environmental quality (or the smaller amount of emissions in our paper). For reference, their original definition is "...two relevant policy goals: a better quality of the environment and, at the same time, an increase in employment levels."

[2]The other theoretical papers that assume a closed economy include Wagner (2005) and Hadjidema and Eleftheriou (2013). Wagner (2005) integrates environmental taxes into a standard search and matching model of Pissarides (2000). It shows that the hypothesis holds and the effect of more strict environmental regulations on welfare depends on the ex ante level of taxes. Hadjidema and Eleftheriou (2013) also develop a search and matching model with emissions (but abstracting from the Nash bargaining) and show that whether the hypothesis holds depends on an elasticity of the amount of emissions to a hiring cost.

[3]This mixed result applies to empirical studies as well. Carraro et al. (1996) simulate their large-scale model for Europe and find that though the hypothesis holds in the short run, it is rejected in the long run. More recent papers of Yamazaki (2017) and Yip (2018) evaluate the impact of revenue-neutral carbon tax introduced in British Columbia in 2008 on employment. Yamazaki (2017) uses the *industry*-level data and support the hypothesis, while Yip (2018), using the *individual*-level data, reject the hypothesis. Yang et al. (2020) examine the carbon emission trading policy in China using the panel data for industrial enterprises in 30 Chinese provinces and cities over the period 2006 to 2016 and support the hypothesis.

Second, welfare analysis is absent in their model. Since welfare is an ultimate criterion to assess a policy in the model, we pay special attention to welfare analysis. This allows us to evaluate whether, for example, trade liberalization is desirable even if it rejects an employment double-dividend hypothesis.

There are three closely related studies. First, Kreickemeier and Richter (2014) develop a two-country asymmetric Melitz model in which intermediate goods generate pollution during their production. They show that trade liberalization has three impacts on an economy: (i) it increases aggregate domestic output (ii) it reduces domestic emissions due to the *reallocation effect* iff emission intensities strongly decrease with firm productivity, and (iii) it has ambiguous impacts on the amount of emissions when local pollution from the other country is considered. Though their model shares key elements such as firm heterogeneity, the environment, and trade liberalization, as they assume the *frictionless* labor market, our model suits better with the analysis of an employment double-dividend hypothesis and is more oriented to the welfare analysis for reasons described above.

Second, Sugiyama and Saito (2016) construct a two-sector small open economy in which skilled and unskilled labors may be unemployed due to the fair wage effort hypothesis. In their model, a downstream final-goods sector generates pollution and is thus subject to an emissions tax, while an upstream eco-industry goods sector receives a subsidy from the government. Their focus, however, is rather on the effects of environmental policies on wage inequality, the amount of emissions, and welfare, and the analysis of an employment double-dividend hypothesis is a by-product. Moreover, as they assume *homogeneous* firms, reallocation effects that play a key role in our paper are absent, and there is no trade liberalization in their paper.

Third, Wang et al. (2020) develop a closed-economy model in which a market structure is duopoly, the industry consists of two symmetric firms that generate pollution, and wage is determined according to the Nash bargaining in the presence of trade union. They show that an increase in emissions taxes have two conflicting impacts on employment: while output is lowered due to higher taxes, they cause the wage to fall. On net, as the former dominates the latter, an increase in emission taxes leads to a decrease in employment, hence rejecting the hypothesis. Their model, however, assumes a closed economy and, by construction, they cannot analyze the impact of trade liberalization. Besides, as there is no labor market friction, the rate of unemployment is exogenous, whereas it is endogenous in our model.

Our paper is organized as follows. Section 2 presents our model. Section 3 analytically decomposes the impact of trade liberalization on major aggregate variables including the amount of emissions and welfare into four forces. Section 4 simulates our model to shed further light on welfare effects of trade liberalization and an environmental policy when trade interacts with the environment. Concluding remarks appear in Section 5.

2. The Model

In this section, extending Felbermayr et al. (2011), we develop our trade model with firm heterogeneity, search and matching frictions, and emissions. The world consists of $n+1$ symmetric countries. Labor is the sole factor of production in inelastic supply L for each country, and is immobile across countries. Throughout the paper, we simplify the notation by suppressing country index due to symmetry.

2.1. Final-goods Firms

The final good generates pollution Z during its production. Thus, final-goods firms face a price $t > 0$ or an emissions tax for each unit of emissions that they release. They minimize their cost

$$tZ + P_X X, \tag{1}$$

subject to the following technology:

$$Y = Z^\alpha X^{1-\alpha}, \quad X \equiv \left(M^{-\frac{1}{\sigma}} \int_{\omega\in\Omega} q_D(\omega)^{\frac{\sigma-1}{\sigma}} d\omega + nM^{-\frac{1}{\sigma}} \int_{\omega\in\Omega} q_{EX}(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}}, \tag{2}$$

where ω indexes varieties, Y is the final good, P_X the price of X, M the mass of available intermediate goods, $q_i(\omega)$ intermediate goods ($i = D, EX$), Ω the set of varieties, $\alpha \in (0,1)$ the share of emission charges in the value of output, and $\sigma > 1$ the elasticity of substitution between varieties.[4] From (1) and (2), we find:

$$X = \left(\frac{t}{AP_X}\right)^\alpha Y, \quad Z = \left(\frac{AP_X}{t}\right)^{1-\alpha} Y, \quad A \equiv \frac{\alpha}{1-\alpha}, \tag{3}$$

where the price index is

$$P_X = \left(M^{-1} \int_{\omega\in\Omega} p_D(\omega)^{1-\sigma} d\omega + nM^{-1} \int_{\omega\in\Omega} p_{EX}(\omega)^{1-\sigma} d\omega \right)^{\frac{1}{1-\sigma}}. \tag{4}$$

Here, $p_i(\omega)$ is the price of variety ω. Following Egger and Kreickemeier (2009) and Felbermayr et al. (2011), we choose X as our numéraire, so that $P_X = 1$ in what follows. The household's demand for each variety ω is then given by:

$$q_i(\omega) = p_i(\omega)^{-\sigma} \frac{X}{M}. \tag{5}$$

2.2. Intermediate-goods Firms

Intermediate-goods firms maximize their profits

$$\begin{aligned} &\pi_D(\varphi) + I(\varphi) n \pi_{EX}(\varphi) \\ &= p_D(\varphi) q_D(\varphi) - w(\varphi) l_D(\varphi) - f_D + I(\varphi) n [p_{EX}(\varphi) q_{EX}(\varphi) - w(\varphi) l_{EX}(\varphi) - f_{EX}], \end{aligned} \tag{6}$$

subject to the household's demand (5) and their production functions

$$q_D(\varphi) = \varphi l_D(\varphi), \quad \tau q_{EX}(\varphi) = \varphi l_{EX}(\varphi), \tag{7}$$

[4] The technology for X is due to Blanchard and Giavazzi (2003); see Egger and Kreickemeier (2009) and Felbermayr et al. (2011) for more detailed discussion of this technology.

where $\varphi > 0$ is firm productivity, $w(\varphi)$ the wage, $l_i(\varphi)$ labor, f_D a fixed production cost, f_{EX} a fixed exporting cost, $I(\varphi)$ an indicator function that equals 1 if a firm exports and 0 otherwise, and $\tau > 1$ iceberg variable costs of trade, whereby τ units of each variety must be exported for one unit to arrive in the foreign country. The optimal pricing rules are:

$$p_D(\varphi) = \left(\frac{\sigma}{\sigma - 1}\right)\frac{w}{\varphi}, \quad p_{EX}(\varphi) = \tau\left(\frac{\sigma}{\sigma - 1}\right)\frac{w}{\varphi}. \tag{8}$$

Thus, equilibrium prices in the export market are a constant multiple of those in the domestic market due to τ: $p_{EX}(\varphi) = \tau p_D(\varphi)$. The household's demand (5) then implies $q_{EX}(\varphi) = \tau^{-\sigma} q_D(\varphi)$ and together these imply $r_{EX}(\varphi) = \tau^{1-\sigma} r_D(\varphi)$ where $r_i(\varphi)$ is firm revenue. Firm profits in each market equal variable profits minus the relevant fixed cost:

$$\pi_D(\varphi) = \frac{r_D(\varphi)}{\sigma} - f_D, \quad \pi_{EX}(\varphi) = \frac{r_{EX}(\varphi)}{\sigma} - f_{EX}. \tag{9}$$

To sum up, the relative price, output, revenue, and employment of any two firms within the same market depends solely on their relative productivities:

$$\frac{p_i(\varphi_1)}{p_i(\varphi_2)} = \frac{\varphi_2}{\varphi_1}, \quad \frac{q_i(\varphi_1)}{q_i(\varphi_2)} = \left(\frac{\varphi_1}{\varphi_2}\right)^{\sigma}, \quad \frac{r_i(\varphi_1)}{r_i(\varphi_2)} = \left(\frac{\varphi_1}{\varphi_2}\right)^{\sigma-1}, \quad \frac{l_i(\varphi_1)}{l_i(\varphi_2)} = \left(\frac{\varphi_1}{\varphi_2}\right)^{\sigma-1}. \tag{10}$$

2.3. The Labor Market and the Value of a Firm

There are search and matching frictions in the labor market. Firms and workers have to spend resources before job creation and production take place. A matching function $\mathcal{M}(v, u) = \Lambda v^{1-\xi} u^{\xi}$ gives the number of jobs formed as a function of the number of workers looking for jobs and the number of firms looking for workers, where $\Lambda > 0$, $\xi \in (0, 1)$, v is the vacancy rate, and u is the unemployment rate. Thus, introducing labor market tightness $\theta \equiv v/u$, the rate at which vacant jobs become filled is given by $m(\theta) = \Lambda\theta^{-\xi}$. In every period, unemployed workers receive $b\bar{w}$ during search where $b \in (0, 1)$ is unemployment insurance benefits and $\bar{w}$ is average wage.

Using $r_{EX}(\varphi) = \tau^{1-\sigma} r_D(\varphi)$ and (5), aggregate revenue $R(l; \varphi)$ is

$$\begin{aligned} R(l;\varphi) &= r_D(\varphi) + I(\varphi) n r_{EX}(\varphi) \\ &= \left(\frac{X}{M}\right)^{\frac{1}{\sigma}} \left[1 + I(\varphi) n \tau^{1-\sigma}\right] (\varphi l(\varphi))^{\frac{\sigma-1}{\sigma}}. \end{aligned} \tag{11}$$

A firm maximizes its value $J(l; \varphi)$ subject to (11) and the evolution of employment $l' = (1 - \zeta)l + m(\theta)v$ where l' is employment in the next period and ζ is the job destruction rate:

$$J(l;\varphi) = \max_{v} \frac{1}{1+r}\left(R(l;\varphi) - w(l;\varphi)l - cv + s - f_D + nI(\varphi)(s - f_{EX}) + (1-\delta)J\left(l';\varphi\right)\right),$$

where $c > 0$ is a hiring cost, $s > 0$ is a hiring subsidy, and $\delta \in (0, 1)$ is a bad shock which producing firms face in every period. The first-order condition for v is

$$(1-\delta)\frac{\partial J(l';\varphi)}{\partial l'} = \frac{c}{m(\theta)}. \tag{12}$$

The other is

$$\frac{\partial J(l;\varphi)}{\partial l} = \frac{1}{1+r}\left(\frac{\partial R(l;\varphi)}{\partial l} - \frac{\partial w(l;\varphi)}{\partial l}l - w(l;\varphi) + (1-\delta)\frac{\partial J(l')}{\partial l'}(1-\zeta)\right), \tag{13}$$

where r is the real interest rate.

Now consider the steady state in which $l = l'$. From (12) and (13), we obtain

$$\frac{\partial R(l;\varphi)}{\partial l} = w(l;\varphi) + \frac{\partial w(l;\varphi)}{\partial l}l + \frac{c}{m(\theta)}\left(\frac{r+\Delta}{1-\delta}\right), \tag{14}$$

where $\Delta \equiv \zeta(1-\delta) + \delta$ is the real job destruction rate adjusted by δ.

2.4. Labor Market Equilibrium

A job match yields the monopoly rent. This rent is shared according to the Nash solution to a bargaining problem. The wage derived from the Nash bargaining solution is the $w(l;\varphi)$ that maximizes the weighted product of the worker's and the firm's net return from the job match. The former is the difference between the value of being employed $E(l;\varphi)$ and the value of being unemployed U:

$$\begin{aligned} E(l;\varphi) - U &= \frac{w(l;\varphi) + (1-\Delta)E(l;\varphi) + \Delta U}{1+r} - \frac{b\bar{w} + \theta m(\theta)E(l;\varphi) + (1-\theta m(\theta))U}{1+r} \\ \Rightarrow E(l;\varphi) - U &= \frac{w(l;\varphi) - rU}{r+\Delta}, \end{aligned}$$

and the latter is a marginal increase in the firm value from hiring a worker $\partial J(l;\varphi)/\partial l$. Thus, the Nash bargaining solution is $(1-\beta)[E(l;\varphi) - U] = \beta[\partial J(l;\varphi)/\partial l]$ where $\beta \in (0,1)$ is a relative measure of labor's bargaining strength. Inserting (13) into this solution and rearranging, we can derive a differential equation for $w(l;\varphi)$:

$$w(l;\varphi) = -\beta\frac{\partial w(l;\varphi)}{\partial l}l + (1-\beta)rU + \beta\frac{\partial R(l;\varphi)}{\partial l}.$$

The solution to this differential equation is:[5]

$$w(l;\varphi) = (1-\beta)rU + \beta\left(\frac{\sigma}{\sigma-\beta}\right)\frac{\partial R(l;\varphi)}{\partial l}. \tag{15}$$

Differentiating this solution with respect to l, multiplying both sides by l, and substituting the resulting expression into (14), we obtain:

$$w(l;\varphi) = \left(\frac{\sigma}{\sigma-\beta}\right)\frac{\partial R(l;\varphi)}{\partial l} - \frac{c}{m(\theta)}\left(\frac{r+\Delta}{1-\delta}\right), \tag{16}$$

[5]Note from (11) that we have

$$\frac{\partial^2 R(l;\varphi)}{\partial l^2}l = -\frac{1}{\sigma}\frac{\partial R(l;\varphi)}{\partial l}.$$

and combining (16) with (15), we find:

$$w(l;\varphi) = rU + \left(\frac{\beta}{1-\beta}\right)\left(\frac{c}{m(\theta)}\right)\left(\frac{r+\Delta}{1-\delta}\right). \tag{17}$$

(17) shows that the wage is independent of φ. This allows us to assume $\bar{w} = w$ in what follows. To complete the characterization of labor market equilibrium, note that U satisfies the Bellman equation:

$$rU(\theta) = b\bar{w} + \theta m(\theta)[E(l;\varphi) - U] = bw + \theta\left(\frac{\beta}{1-\beta}\right)\left(\frac{c}{1-\delta}\right).$$

Substituting this expression for $rU(\theta)$ into (17), we obtain the *wage equation*:

$$w = B\left(\frac{c}{1-\delta}\right)\left(\frac{r+\Delta}{m(\theta)} + \theta\right), \quad B \equiv \left(\frac{\beta}{1-\beta}\right)\left(\frac{1}{1-b}\right). \tag{18}$$

As shown in Figure 2, the wage equation slopes up. At higher tightness θ, workers are more likely to locate an alternative job offer, and firms are less likely to locate an alternative worker if the wage bargain fails; thus, the worker's hand in the wage bargain strengthens.

Next, we define overall weighted average productivity $\tilde{\varphi}$ so that $q_D(\tilde{\varphi}) = X/M$ as in Egger and Kreickemeier (2009) and Felbermayr et al. (2011). The household's demand (5) then implies $p_D(\tilde{\varphi}) = 1$ as $P_X = 1$. Differentiating (11) with respect to l when $\varphi = \tilde{\varphi}$, we find

$$\frac{\partial R(l;\tilde{\varphi})}{\partial l} = \left(\frac{\sigma-1}{\sigma}\right)\tilde{\varphi},$$

and inserting this into (16), we get the *job creation curve*:

$$w(\tilde{\varphi}) = \left(\frac{\sigma-1}{\sigma-\beta}\right)\tilde{\varphi} - \frac{c}{m(\theta)}\left(\frac{r+\Delta}{1-\delta}\right). \tag{19}$$

As Figure 2 shows, the job creation curve slopes down; at a lower wage rate, jobs are more profitable and more vacancies are created.

Finally, we have the *Beveridge curve*:

$$u(\theta) = \frac{\Delta}{\Delta + \theta m(\theta)}. \tag{20}$$

Therefore, labor market equilibrium is a triple (u,θ,w) that satisfies three equations (18), (19), and (20) as in Pissarides (2000) and is represented by point E_1 in Figure 2. The central point here is that in our model (and in the Felbermayr et al. (2011) model as well), the job creation curve includes $\tilde{\varphi}$. Thus, if trade liberalization leads to a rise in $\tilde{\varphi}$ as in their model, job creation rises and the job creation curve shifts upward. As a result, in response to this trade-induced shock, an economy moves from point E_1 to point E_2 in Figure 2; equilibrium unemployment decreases and vacancies rise.

While these observations are true in our model too, we will later show that our $\tilde{\varphi}$ contains an additional parameter α and an endogenous variable s, a hiring subsidy. As they link the labor market to the environment, we can gain greater insight into an employment double-dividend hypothesis through *reallocation effects* than Felbermayr et al. (2011) and previous related studies that assume *homogeneous* firms.

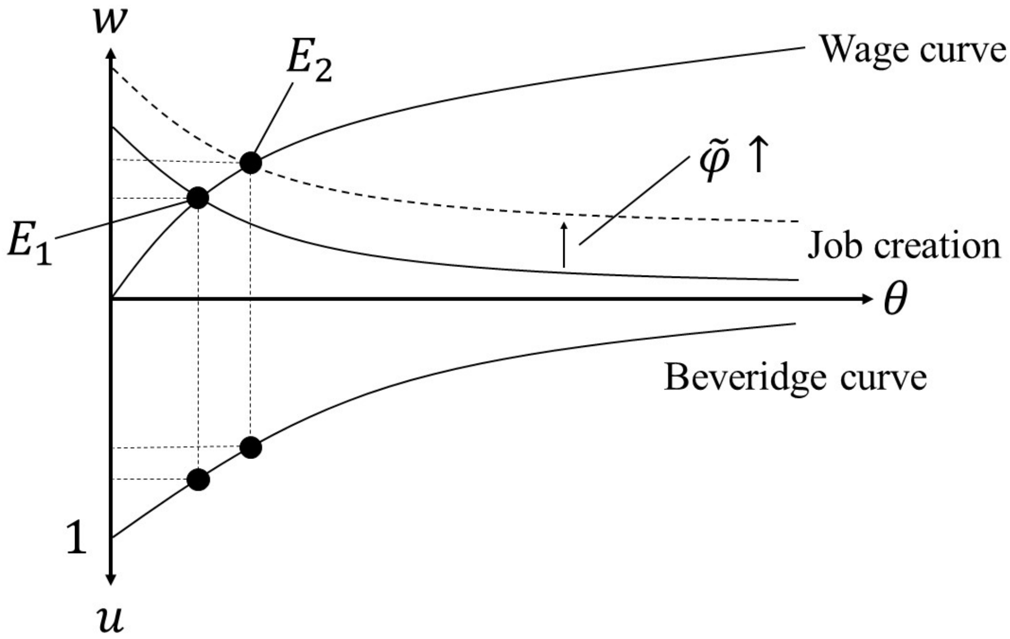

Figure 2: Equilibrium in the labor market with search frictions.

2.5. Productivity Cutoffs

There is a large pool of prospective entrants. Prior to entry, firms are identical. To enter, they must pay a sunk entry cost of f_E. Once f_E is paid, a firm draws its productivity $\varphi > 0$ from a common distribution $g(\varphi)$ that has a continuous cumulative distribution $G(\varphi)$. Upon entry with low φ, a firm decides to exit and not to produce. If a firm produces, it then faces a constant probability $\delta \in (0, 1)$ of a bad shock.

From profit functions $\pi_i(\varphi)$ and (5), we can derive a zero-profit cutoff (ZPC) productivity φ^*_D and an exporting cutoff productivity φ^*_{EX}: $\pi(\varphi^*_i) = 0$ or $r_i(\varphi^*_i) = \sigma f_i$. Their relationship is thus:

$$\varphi^*_{EX} = \tau \left(\frac{f_{EX}}{f_D} \right)^{\frac{1}{\sigma-1}} \varphi^*_D,$$

where we assume $\tau \left(f_{EX}/f_D \right)^{\frac{1}{\sigma-1}} > 1$. The ex post productivity distributions $\mu_i(\varphi)$ in the domestic and export markets are $\mu_i(\varphi) = g(\varphi)/[1 - G(\varphi^*_i)]$ where $1 - G(\varphi^*_D)$ is the probability of successful entry. As a result, the probability of exporting χ is given by $\chi = [1 - G(\varphi^*_{EX})]/[1 - G(\varphi^*_D)]$.

Let M_D denote the mass of producing firms and $M_{EX} = \chi M_D$ the mass of exporting firms. The total mass of firms M is then given by $M = M_D(1 + n\chi)$. From the price index

(4) and using $p_D(\varphi) = \tilde{\varphi}/\varphi$ in (10), we obtain $\tilde{\varphi}$ as follows:

$$1 = \left(M^{-1} \int_{\varphi_D^*}^{\infty} p_D(\varphi)^{1-\sigma} \mu_D(\varphi) M_D d\varphi + nM^{-1} \int_{\varphi_{EX}^*}^{\infty} p_{EX}(\varphi)^{1-\sigma} \mu_{EX}(\varphi) M_{EX} d\varphi \right)^{\frac{1}{1-\sigma}}$$

$$\Leftrightarrow \tilde{\varphi} = \left[\left(\frac{1}{1+n\chi} \right) \left(\tilde{\varphi}_D^{\sigma-1} + n\chi\tau^{1-\sigma} \tilde{\varphi}_{EX}^{\sigma-1} \right) \right]^{\frac{1}{\sigma-1}}, \quad \tilde{\varphi_i}^{\sigma-1} \equiv \int_{\varphi_i}^{\infty} \varphi^{\sigma-1} \mu_i(\varphi) d\varphi. \tag{21}$$

Thus, $\tilde{\varphi}$ itself is a weighted average of weighted-average productivities in the domestic and export markets. Now, for an analytical inquiry, we assume a Pareto productivity distribution: $G(\varphi) = 1 - \varphi^{-k}$ and $g(\varphi) = k\varphi^{-(k+1)}$ where we normalize the lower bound of the support of the productivity distribution to one. $k > 1$ is the shape parameter; *lower* k means *greater* dispersion in φ. Following the literature, we require $k > \sigma - 1$ for average firm revenue in each market to have a finite mean.

With a Pareto productivity distribution, $\tilde{\varphi}_i$ can be evaluated as:

$$\tilde{\varphi}_i = \left(\frac{k}{k-(\sigma-1)} \right) \varphi_i^* \Rightarrow \frac{\tilde{\varphi}_D}{\varphi_D^*} = \frac{\tilde{\varphi}_{EX}}{\varphi_{EX}^*}, \quad \frac{\varphi_{EX}^*}{\varphi_D^*} = \frac{\tilde{\varphi}_{EX}}{\tilde{\varphi}_D},$$

and this allows us to find:

$$\tilde{\varphi} = \left(\frac{1 + n\tau^{-k} \left(\frac{f_{EX}}{f_D} \right)^{\frac{-k+(\sigma-1)}{\sigma-1}}}{1 + n\tau^{-k} \left(\frac{f_{EX}}{f_D} \right)^{\frac{-k}{\sigma-1}}} \right)^{\frac{1}{\sigma-1}} \tilde{\varphi}_D. \tag{22}$$

The firm's operating profit is given by

$$\Pi_i(\varphi) = \underbrace{\left(\frac{1-\delta}{r+\delta} \right)}_{=\sum_{t=1}^{\infty} \left(\frac{1-\delta}{1+r} \right)^t} \left(p_i(\varphi)\varphi l_i(\varphi) + s - wl_i(\varphi) - \frac{c}{m(\theta)} \zeta l_i(\varphi) - f_i \right) - \frac{c}{m(\theta)} l_i(\varphi) - f_i.$$

Rearranging the firm's operating profit as

$$\Pi_i(\varphi) = \Gamma(w,\theta) l_i(\varphi) + (1-\delta)s - (1+r)f_i, \quad \Gamma(w,\theta) \equiv (1-\delta) \left(\frac{w}{\sigma-1} - \frac{c(r+\delta)}{m(\theta)} \right),$$

we can derive the following ratio:

$$\frac{\Pi_i(\tilde{\varphi}_i) + (1+r)f_i - (1-\delta)s}{\underbrace{\Pi_i(\varphi_i^*)}_{(=0)} + (1+r)f_i - (1-\delta)s} = \left(\frac{\tilde{\varphi}_i}{\varphi_i^*} \right)^{\sigma-1}.$$

Therefore, the *ZPC condition* is:

$$\Pi_i(\tilde{\varphi}_i) = [(1+r)f_i - (1-\delta)s]\left(\left(\frac{\tilde{\varphi}_i}{\varphi_i^*}\right)^{\sigma-1} - 1\right).$$

The firm's combined operating profit can be written as:

$$\begin{aligned}\tilde{\Pi} &\equiv \Pi_D(\tilde{\varphi}_D) + n\chi\Pi_{EX}(\tilde{\varphi}_{EX}) \\ &= \left(\frac{\sigma-1}{k-(\sigma-1)}\right)\left[(1+r)f_D\left(1+n\tau^{-k}\left(\frac{f_{EX}}{f_D}\right)^{\frac{-k+\sigma-1}{\sigma-1}}\right) - (1-\delta)s\left(1+n\tau^{-k}\left(\frac{f_{EX}}{f_D}\right)^{\frac{-k}{\sigma-1}}\right)\right],\end{aligned}$$

and the *free entry (FE) condition* is thus:

$$f_E = \frac{\tilde{\Pi}}{r+\delta}[1-G(\varphi_D^*)] \Leftrightarrow f_E(r+\delta)\varphi_D^{*k} = \tilde{\Pi}.$$

As in Melitz (2003), the ZPC condition and FE condition identify a ZPC productivity:[6]

$$\begin{aligned}\varphi_D^* = &\left(\frac{\sigma-1}{f_E(r+\delta)[k-(\sigma-1)]}\right)^{\frac{1}{k}} \\ &\times\left[(1+r)f_D\left(1+n\tau^{-k}\left(\frac{f_{EX}}{f_D}\right)^{\frac{-k+\sigma-1}{\sigma-1}}\right) - (1-\delta)s\left(1+n\tau^{-k}\left(\frac{f_{EX}}{f_D}\right)^{\frac{-k}{\sigma-1}}\right)\right]^{\frac{1}{k}},\end{aligned} \tag{23}$$

and the average productivity level:

$$\tilde{\varphi} = \left[\left(\frac{k}{k-(\sigma-1)}\right)\left(\frac{1+n\tau^{-k}\left(\frac{f_{EX}}{f_D}\right)^{\frac{-k+\sigma-1}{\sigma-1}}}{1+n\tau^{-k}\left(\frac{f_{EX}}{f_D}\right)^{\frac{-k}{\sigma-1}}}\right)\right]^{\frac{1}{\sigma-1}}\varphi_D^*. \tag{24}$$

2.6. Aggregation

Equilibrium in the labor market implies:

$$\begin{aligned}(1-u)L &= \int_{\varphi_D^*}^{\infty} l_D(\varphi)M_D\mu_D(\varphi)d\varphi + n\int_{\varphi_{EX}^*}^{\infty} l_{EX}(\varphi)M_{EX}\mu_{EX}(\varphi)d\varphi \\ &= l_D(\tilde{\varphi})M.\end{aligned} \tag{25}$$

Now, note that output per firm can be calculated as:

$$q_D(\tilde{\varphi}) = r_D(\tilde{\varphi}) = r_D(\varphi_D^*)\left(\frac{\tilde{\varphi}}{\varphi_D^*}\right)^{\sigma-1} = \left(\frac{k\sigma f_D}{k-(\sigma-1)}\right)\left(\frac{1+n\tau^{-k}\left(\frac{f_{EX}}{f_D}\right)^{\frac{-k+\sigma-1}{\sigma-1}}}{1+n\tau^{-k}\left(\frac{f_{EX}}{f_D}\right)^{\frac{-k}{\sigma-1}}}\right),$$

[6] We discuss the nonnegativity constraint on φ_D^* after deriving the equilibrium value of a hiring subsidy s.

as $p_D(\tilde{\varphi}) = 1$. Thus, from (25), we obtain the equilibrium total mass of firms:

$$M = \frac{(1-u)L}{l_D(\tilde{\varphi})} = \frac{(1-u)L\tilde{\varphi}}{q_D(\tilde{\varphi})}. \tag{26}$$

From (3), (26) then pins down the rest of aggregate variables:

$$X = Mq_D(\tilde{\varphi}), \quad Y = \left(\frac{A}{t}\right)^{\alpha} X, \quad Z = \left(\frac{A}{t}\right)^{1-\alpha} Y, \tag{27}$$

and (27) in turn allows us to define a social welfare function:[7]

$$\mathbb{W} \equiv Y - Z. \tag{28}$$

2.7. Government and a Hiring Subsidy

The government uses its revenues from an emissions tax tZ to finance its expenditure: a hiring subsidy s to firms. We make two assumptions to simplify our analysis. First, the government runs a balanced budget in every period. Second, the government does not give s to firms that are hit by a bad shock δ. Under these two assumptions, we have

$$tZ = s(1-\delta)M,$$

which, due to (27), boils down to:

$$s(\tau, n, \alpha) = \left[\frac{A(\alpha)}{1-\delta}\right] q_D(\tilde{\varphi}). \tag{29}$$

Therefore, in response to trade liberalization or changes in α, the government adjusts the amount of s so that its budget balances out.

Now that we have derived all equilibrium conditions, before analyzing the effects of trade and its implications for an employment double-dividend hypothesis, we can discuss the nonnegativity constraint on φ_D^*. Specifically, from (23) and (29), it is given by:

$$A(\alpha) < (1+r)\left(\frac{k-(\sigma-1)}{k\sigma}\right).$$

As we see, this inequality is more likely to be satisfied when α is low; that is, final-goods firms release lower emissions as, for example, they have already invested enough in abatement technology. We assume that this inequality is satisfied so that $\varphi_D^* > 0$ in what follows. For future reference, we call a policy that lowers α *environmental technological progress.*

[7] This form is just for simplicity and transparency. Adopting a more general formulation such as

$$\mathbb{W} \equiv Y - \gamma\frac{Z^2}{2},$$

does not qualitatively change any of our results that follow.

3. Comparative Statics

3.1. Preliminaries

In this section, we investigate the effects of trade and an environmental policy. To begin with, as in Melitz (2003), trade liberalization (a decrease in trade costs τ or an increase in the number of trading partners n) leads to a rise in φ_D^*:

$$\frac{\partial \varphi_D^*}{\partial \tau} < 0, \quad \frac{\partial \varphi_D^*}{\partial n} > 0, \quad \frac{\partial \varphi_D^*}{\partial \alpha} < 0.$$

Our new result is that environmental technological progress also leads to a *rise* in φ_D^*. To see why, note from (2), (3), and (5) that lower α means a stronger final-goods firm's demand for each variety. Since this leads to larger revenues, intermediate-goods firms now earn higher profits. As a result, due to the presence of the incumbents with higher profits, the entry of new firms into the markets becomes more difficult, resulting in a rise in φ_D^*.

Applying these results, a response of $\tilde{\varphi}$ that shifts the job creation curve can be written as:

$$\frac{\partial \tilde{\varphi}/\partial \tau}{\tilde{\varphi}} = \left(\frac{1}{\sigma - 1}\right) \varphi_D^{*-1} \underbrace{\frac{\partial q_D(\tilde{\varphi})/\partial \tau}{q_D(\tilde{\varphi})}}_{(-)} + \frac{\partial \varphi_D^*/\partial \tau}{\varphi_D^*} < 0,$$

and similarly, we obtain $\partial \tilde{\varphi}/\partial n > 0$ and $\partial \tilde{\varphi}/\partial \alpha < 0$. Therefore, as expected from (24), the qualitative responses of φ_D^* and $\tilde{\varphi}$ coincides.

This allows us to revisit Figure 2. As in Felbermayr et al. (2011), since trade liberalization leads to a rise in $\tilde{\varphi}$, the job creation curve shifts upward. Our new finding is that environmental technological progress does the same: when final-goods firms invest more in abatement technology, it leads to a rise in $\tilde{\varphi}$ and thus shifts the job creation curve upward. As a result, an economy moves from point E_1 to point E_2; vacancies rise and equilibrium unemployment decreases. We can summarize the partial derivatives of u as follows to analyze an employment double-dividend hypothesis later:

$$\frac{\partial u}{\partial \tau} > 0, \quad \frac{\partial u}{\partial n} < 0, \quad \frac{\partial u}{\partial \alpha} > 0.$$

The total mass of firms M plays a significant role to investigate the responses of the rest of aggregate variables (see (27)). Thus, it's worthwhile to carefully understand its response to trade liberalization and environmental technological progress to develop better intuition for our results. First, the result for the former is:[8]

$$\begin{aligned} \frac{\partial M/\partial \tau}{M} &= \frac{\partial (1-u)/\partial \tau}{1-u} - \frac{\partial l_D(\tilde{\varphi})/\partial \tau}{l_D(\tilde{\varphi})} \\ &= \underbrace{\frac{\partial (1-u)/\partial \tau}{1-u}}_{(-)} + \underbrace{\left(\frac{2-\sigma}{\sigma-1}\right)}_{(?)} \underbrace{\frac{\partial q_D(\tilde{\varphi})/\partial \tau}{q_D(\tilde{\varphi})}}_{(-)} + \underbrace{\frac{\partial \varphi_D^*/\partial \tau}{\varphi_D^*}}_{(-)} \begin{cases} < 0 & \sigma \in (1,2) \\ \lesseqgtr 0 & \sigma > 2. \end{cases} \end{aligned} \tag{30}$$

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[8]For brevity, we focus on τ from this point on. n plays qualitatively the same role.

As we see, the impact of trade liberalization on M can be decomposed into *three* terms. The first term captures a trade-induced increase in labor supply $(1-u)L$ that leads to an increase in M; the second captures a trade-induced increase in output per firm $q_D(\tilde{\varphi})$ that may lead to an increase or a decrease in M depending on how high or low σ is; and the third captures a trade-induced rise in a ZPC productivity that leads to an increase in M. When $\sigma \in (1,2)$ and markets are *less* competitive, these three forces have the same qualitative impact on M: trade liberalization leads to an *increase* in M. In contrast, when $\sigma > 2$ and markets are *more* competitive, the second force has the negative impact on M. Thus, in this case, if the second force dominates the other two, trade liberalization may lead to a *reduction* in M.

Next, the impact of environmental technological progress on M is given by:

$$\frac{\partial M/\partial \alpha}{M} = \underbrace{\frac{\partial(1-u)/\partial \alpha}{1-u}}_{(-)} + \underbrace{\frac{\partial \varphi_D^*/\partial \alpha}{\varphi_D^*}}_{(-)} < 0. \tag{31}$$

Compared with (30), the second term drops out as $q_D(\tilde{\varphi})$ is independent of α. Therefore, environmental technological progress leads to an increase in labor supply and to a rise in a ZPC productivity and, in turn, an *increase* in M.

3.2. An Employment Double-Dividend Hypothesis

From (27), (30) and (31), we find:

$$\frac{\partial X/\partial \tau}{X} = \underbrace{\frac{\partial M/\partial \tau}{M}}_{(?)} + \underbrace{\frac{\partial q_D(\tilde{\varphi})/\partial \tau}{q_D(\tilde{\varphi})}}_{(-)} \begin{cases} < 0 & \sigma \in (1,2) \\ \lesseqgtr 0 & \sigma > 2 \end{cases}, \quad \frac{\partial X/\partial \alpha}{X} = \frac{\partial M/\partial \alpha}{M} < 0, \tag{32}$$

$$\frac{\partial Y/\partial \tau}{Y} = \frac{\partial X/\partial \tau}{X} \begin{cases} < 0 & \sigma \in (1,2) \\ \lesseqgtr 0 & \sigma > 2 \end{cases}, \quad \frac{\partial Y/\partial \alpha}{Y} = \alpha t \underbrace{\frac{\partial A/\partial \alpha}{A}}_{(+)} + \underbrace{\frac{\partial X/\partial \alpha}{X}}_{(-)} \gtrless 0, \tag{33}$$

$$\frac{\partial Z/\partial \tau}{Z} = \frac{\partial Y/\partial \tau}{Y} \begin{cases} < 0 & \sigma \in (1,2) \\ \lesseqgtr 0 & \sigma > 2 \end{cases}, \quad \frac{\partial Z/\partial \alpha}{Z} = (1-\alpha) t \underbrace{\frac{\partial A/\partial \alpha}{A}}_{(+)} + \underbrace{\frac{\partial Y/\partial \alpha}{Y}}_{(?)} \gtrless 0, \tag{34}$$

(32), together with (30), shows that the impact of trade liberalization on X (and subsequently on the final good Y and pollution Z) can be decomposed into *four* forces: three forces through changes in M described above plus the direct (that is, independent of σ) positive force due to an increase in output per firm $q_D(\tilde{\varphi})$. Therefore, the impact of trade liberalization on the amount of emissions depends on how competitive markets are and, of four forces, which one dominates the other(s).

For the effects of environmental technological progress, notice that α affects Y and Z through *two* channels: an emissions tax (t) channel and a total mass of firms (M) channel. As they have the opposite effect on Y and Z, the impact of environmental technological progress on Y and Z is positive *or* negative. Notice also that the first term in (33) and (34) is more likely to dominate the second as an emissions tax rises, or environmental regulations become more strict. This property is useful when we analyze the welfare effects of environmental technological progress.

Now, recall $\partial u/\partial \tau > 0$ and $\partial u/\partial \alpha > 0$. Then, from (34), our insight into an employment double-dividend hypothesis can be summarized as follows:

Proposition 1. *Trade liberalization affects the amount of emissions through four channels. When markets are less competitive, trade liberalization does not deliver an employment double dividend. In contrast, when markets are more competitive, it may deliver an employment double dividend.*

Proposition 2. *Due to an emissions tax channel and a total mass of firms channel, environmental technological progress can or cannot deliver an employment double dividend. Which force dominates depends on how strict environmental regulations are.*

Thus, our model have the deep insight into why recent empirical studies such as Yamazaki (2017), Yip (2018), and Yang et al. (2020) reach the conflicting conclusion that an employment double-dividend hypothesis holds or is rejected by decomposing the impact of trade liberalization and environmental technological progress on the amount of emissions into four or two forces.

3.3. Welfare

To analyze whether an employment double-dividend hypothesis holds is a sufficient condition to evaluate a policy but not a *necessary* condition. Thus, we now briefly examine the welfare effects of trade liberalization and environmental technological progress. Differentiating a social welfare function (28) with respect to τ, we obtain:

$$\begin{aligned}\frac{\partial \mathbb{W}}{\partial \tau} &= \frac{\partial Y}{\partial \tau} - \frac{\partial Z}{\partial \tau} \\ &= \left(\frac{A}{t}\right)^{\alpha}\left(1-\left(\frac{A}{t}\right)^{1-\alpha}\right) M \left(\underbrace{\frac{\partial M/\partial \tau}{M}}_{(?)} q_D(\tilde{\varphi}) + \underbrace{\frac{\partial q_D(\tilde{\varphi})}{\partial \tau}}_{(-)}\right) \begin{cases} < 0 & \sigma \in (1,2) \\ \lesseqgtr 0 & \sigma > 2 \end{cases}. \end{aligned} \tag{35}$$

As in Proposition 1, unlike Melitz (2003), trade liberalization improves or *deteriorates* welfare due to four counteracting forces described above. In the same vein, differentiating (28) with respect to α, we find:

$$\frac{\partial \mathbb{W}}{\partial \alpha} = \frac{\partial Y}{\partial \alpha} - \frac{\partial Z}{\partial \alpha} = t\left[\alpha Y - (1-\alpha) Z\right]\left(2 \times \underbrace{\frac{\partial A/\partial \alpha}{A}}_{(+)} + \underbrace{\frac{\partial X/\partial \alpha}{X}}_{(-)} + \underbrace{\frac{\partial Y/\partial \alpha}{Y}}_{(?)}\right) \gtrless 0.$$

Thus, the welfare effects of our model can be summarized as follows:

Proposition 3. *Due to several conflicting forces, trade liberalization and environmental technological progress improve or deteriorate welfare.*

4. Simulation

Up to this point, we have not analyzed how trade liberalization interacts with the environment. Also, our overall comparative statics suggests that the impact of trade liberalization and environmental technological progress on aggregate variables is in general indeterminate. Thus, it is of interest to know which force will dominate by simulating our model using the typical parameter values used in the literature. This allows us to shed further light on welfare effects of trade and environmental policies on an employment double-dividend hypothesis.

4.1. Welfare

Our baseline parameterization of course is based on Felbermayr et al. (2011): $\beta = 0.5$, $\xi = 0.5$, $\Delta = 0.034$, $r = 0.0033$, $k = 3.4$, $\sigma = 3.8$, $f_{EX} = 3.01$, $f_D = 1.77$, $f_E = 39.57$, $\delta = 0.0097$, $\tau = 1.3$, $b = 0.4$, $\Lambda = 0.64$, $c = 4.73$, $L = 1$, and $n = 2$. For α, we use $\alpha = 0.011$ based on Shapiro and Walker (2018) and for t, we use $t = 0.10$ for our baseline simulation.[9]

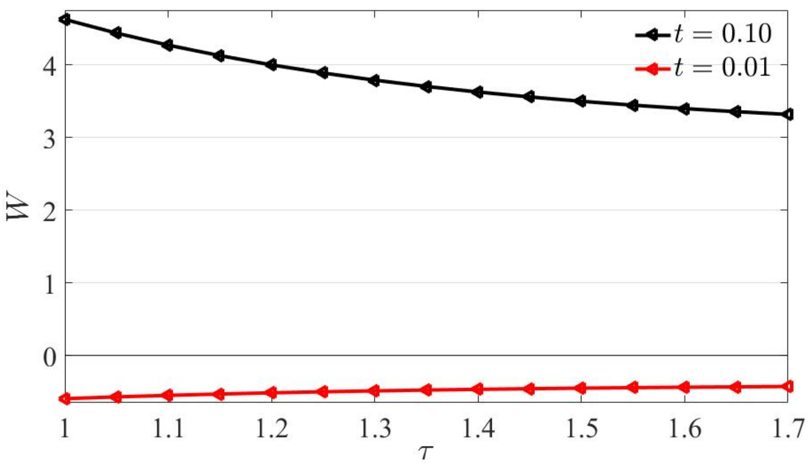

Figure 3: The impact of trade liberalization on welfare when $t = 0.10$ (black line) and $t = 0.01$ (red line).

Figure 3 shows the responses of welfare to trade liberalization for a baseline case of $t = 0.10$ and a case of weak environmental regulations $t = 0.01$. As we see, while trade liberalization improves welfare in an economy with strict environmental regulations, it *deteriorates* welfare in an economy with weak environmental regulations. Therefore, to benefit from trade liberalization, a country may want more strict environmental regulations. This numerical result is thus consistent with (35) and the theoretical prediction from (27) and (28):

$$\frac{\partial \mathbb{W}}{\partial t} = \underbrace{\frac{\partial Y}{\partial t}}_{(-)} - \underbrace{\frac{\partial Z}{\partial t}}_{(-)} \gtrless 0.$$

[9] Though our most parameter values are chosen to be somewhat realistic, as in Felbermayr et al. (2011), the main point is to show our *qualitative* results in a transparent and an intuitive way.

Next, Figure 4 illustrates the responses of major aggregate variables to trade liberalization for three values of α. Panel (a) shows that lower α leads to a further rise in a ZPC productivity φ_D^* in response to trade liberalization. Therefore, given a one-to-one correspondence between φ_D^* and $\tilde{\varphi}$, trade liberalization, combined with environmental technological progress, further shifts the job creation curve upward in Figure 2. This translates into a larger decrease in the rate of unemployment for three values of α as shown in panel (b).

For aggregate variables shown in panels (c) to (e) and welfare (f), their qualitative responses are the same; they go in the same direction in response to trade liberalization regardless of α. Note, however, that lower α leads to an increase in Y and the smaller amount of Z. Thus, as panel (f) shows, a country that has invested enough in abatement technology tends to benefit better from trade liberalization. The results of our numerical welfare analysis so far can be summarized as follows:

Proposition 4. *In an economy with weaker environmental regulations, trade liberalization delivers a welfare loss. In contrast, trade liberalization delivers a welfare gain in an economy with stronger environmental regulations or an economy that has invested enough in abatement technology. Thus, a country that pays little attention to the environment is less likely to benefit from trade liberalization.*

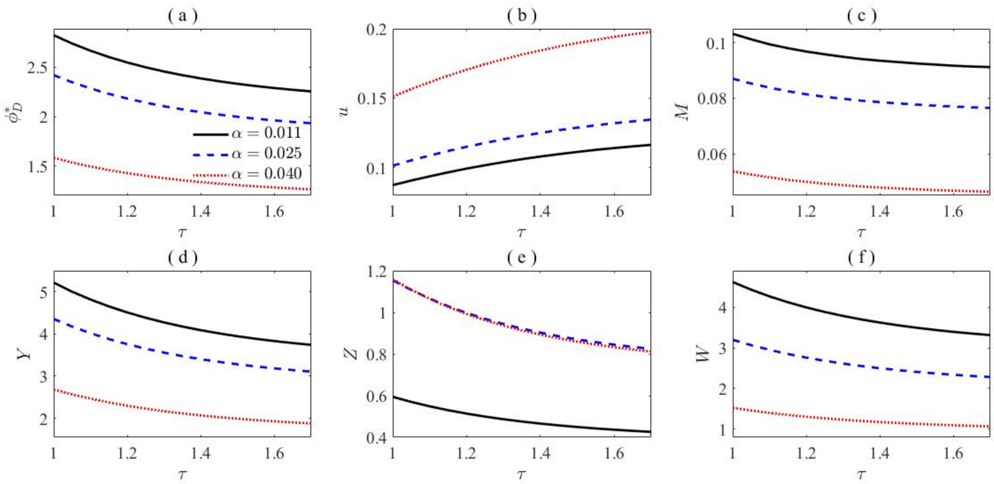

Figure 4: The impact of trade liberalization on a ZPC productivity (a), the unemployment rate (b), the total mass of firms (c), aggregate output (d), emissions (e), and welfare (f) for $\alpha = 0.011$ (black solid line), $\alpha = 0.025$ (blue dashed line), and $\alpha = 0.040$ (red dotted line).

4.2. An Employment Double-Dividend Hypothesis

To test an employment double-dividend hypothesis, we put panels (b) and (e) of Figure 4 together in Figure 5. It makes clear that, regardless of α, the hypothesis is *rejected*; an economy *cannot* jointly lower the rate of unemployment and improve environmental quality by liberalizing trade. Though trade liberalization lowers the rate of unemployment, the amount of emissions gets larger (as indicated by the arrows on each line in Figure 5).

At the same time, note that Figure 5 is in favor of environmental technological progress. For example, an economy with $\alpha = 0.040$ suffers more from the *higher* rate of unemployment and the *larger* amount of emissions than an economy with $\alpha = 0.011$ that suffers from the *lower* rate of unemployment and the *smaller* amount of emissions. Thus, by deliberately investing in abatement technology, an economy can transit from a *dirty equilibrium* with high unemployment to a *clean equilibrium* with low unemployment (a move from the upper right to the lower left in Figure 5). Also, this transition is desirable from the welfare viewpoint.[10] The results of our numerical test of an employment double-dividend hypothesis can be summarized as follows:

Proposition 5. *For assumed parameter values, an employment double-dividend hypothesis is rejected. A deliberate investment in abatement technology, however, enables an economy to transit from a dirty equilibrium with high unemployment to a clean equilibrium with low unemployment. Therefore, even if an economy faces a trade-off, it can be less severe by promoting environmental technological progress.*

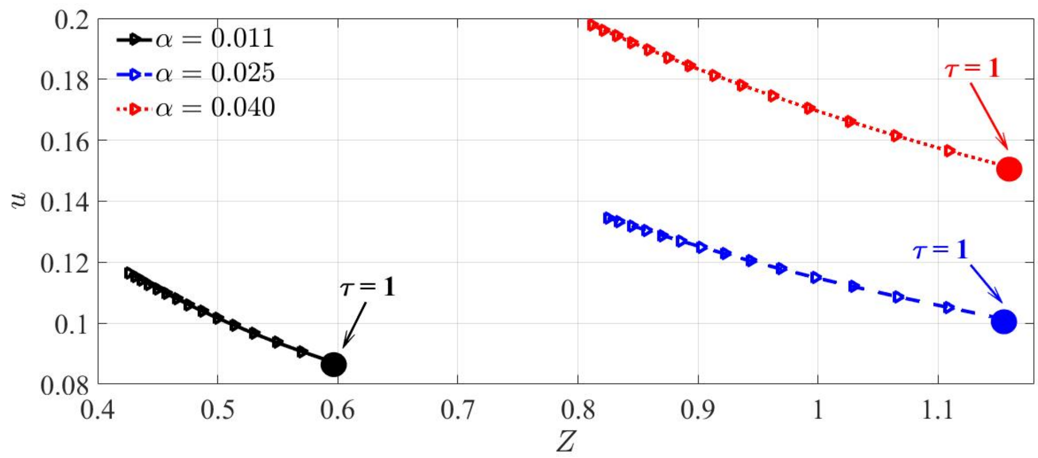

Figure 5: The rejection of an employment double-dividend hypothesis for $\alpha = 0.011$ (black solid line), $\alpha = 0.025$ (blue dashed line), and $\alpha = 0.040$ (red dotted line).

5. Concluding Remarks

Can trade liberalization deliver an employment double dividend and a welfare gain? To answer this question, we have developed a trade model with firm heterogeneity, search and matching frictions, and emissions that is in line with Figure 1. We first analytically

[10]Given Proposition 4, welfare is higher in a clean equilibrium than in a dirty equilibrium.

decompose the impact of trade liberalization on the amount of emissions into four forces: an increase in labor supply that leads to the larger amount of emissions; an increase in output per firm that may lead to the larger or smaller amount of emissions depending on how competitive markets are; a rise in a ZPC productivity that leads to the larger amount of emissions; and an increase in output per firm independent of market competitiveness that leads to the larger amount of emissions. When the second force dominates the others and markets are competitive enough, trade liberalization may support an employment double-dividend hypothesis, or otherwise it rejects the hypothesis. Moreover, due to these four counteracting forces, trade liberalization may deliver a welfare loss.

We then simulate our model to better understand an interaction between trade liberalization, environmental regulations, and welfare. For the typical parameter values used in the literature, an employment double-dividend hypothesis is rejected. A deliberate investment in abatement technology, however, enables an economy to transit from a dirty equilibrium with higher unemployment to a clean equilibrium with lower unemployment. Thus, our overall results suggest that a country paying little attention to the environment is more likely to suffer from higher unemployment and the larger amount of emissions, and is less likely to benefit from trade liberalization.

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