

# Endogenous Labor Supply and the Gains from International Trade\*

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## Abstract

This paper incorporates elastic labor supply into a standard gravity model of trade and characterizes the implications for welfare. We show that gains can be computed using only a few sufficient statistics: the share of expenditure on domestic goods, the trade elasticity, and the elasticity of labor supply. Introducing the consumption-leisure choice delivers gains that may be substantially different from what models with inelastic labor supply predict. In particular, in a setting with a fixed number of varieties, gains from trade are always higher than in trade models with inelastic labor supply and are increasing in the elasticity of labor. In addition, when the number of varieties is endogenous and income effects are small, the increase in labor supply can raise the number of varieties and thus can lead to sizeable gains. Quantitatively, we find that, for the median country in our sample, gains from trade are up to 23% higher than models featuring constant labor supply.

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# 1 Introduction

There is a vast theoretical and empirical literature in macroeconomics and labor economics that studies the response of labor supply to changes in the real wage. The results from this literature have served as the base for numerous studies on the effects of macroeconomic policies (Rogerson and Wallenius (2013), Trabandt and Uhlig (2011), Prescott et al. (2009) and Altonji (1986) among others). Trade economists, in contrast, have hitherto overlooked the endogenous response of labor supply to changes in real wages following a trade liberalization.<sup>1</sup>

In this paper we incorporate elastic labor supply in a standard gravity framework and characterize the response of labor and welfare to changes in trade costs. In particular, we set up the “excess expenditure” minimization problem and compute the equivalent variation in terms of real consumption needed to reach the utility of the counterfactual equilibrium, while keeping the labor supply at its initially chosen level.<sup>2</sup> Our baseline model assumes a separable utility in consumption and labor and a Constant Elasticity of Substitution (CES) consumption aggregator across varieties. We show that when the number of varieties is fixed gains from trade are always higher than in models with inelastic labor supply (namely the class of models considered by Arkolakis et al. (2012b), ACR henceforth).<sup>3</sup> With an endogenous number of varieties, gains depend on the magnitude of income effects: if these effects are sufficiently small, so that labor supply rises after a trade liberalization, the number of varieties also increases and the gains from trade are substantially higher than ACR.

Furthermore, in our framework the trade structure of standard gravity models is retained intact so that welfare calculations only depend on a few sufficient statistics, in the spirit of ACR. In particular, our model requires estimates of the trade and labor supply elasticities, and the only endogenous variable needed is the share of expenditure on domestic goods. Using empirical estimates for the aggregate trade elasticity and the aggregate Hicksian elasticity of labor (taken respectively from Simonovska and Waugh (2014) and Chetty (2012)), we can compute the gains of going from complete autarky to the status-quo level of trade, as in ACR and Costinot and Rodríguez-Clare (2013).<sup>4</sup> These gains from trade in our model

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<sup>1</sup>There is however a growing literature that studies the interaction between labor demand and trade.

<sup>2</sup>For the notion of “excess” expenditure minimization see Rogerson (2013), Facchini and Willmann (1999), Ashenfelter (1980) and McFadden (1978) among others.

<sup>3</sup>These models are characterized by: Dixit-Stiglitz preferences, perfect or monopolistic competition, balanced trade, aggregate profits that are a constant share of aggregate revenues (possibly zero), and CES import demand.

<sup>4</sup>We could also use estimates of the uncompensated elasticity from Evers et al. (2008), and the resulting

are higher than ACR for all calibrations. In the most complete version of our calibrations, with multiple sectors, the gains for the median country in our sample are up to 23% higher with endogenous number of varieties. Moreover, most of the difference in the gains from trade comes from the variety increase and the corresponding rise in labor supply is relatively small: up to 7.9% for the median country.

Section 2 describes the theoretical relationship between trade, labor supply, and welfare. We first analyze the fixed variety model by Armington (1969) and analytically show that the welfare gains are always higher than ACR and increasing in the labor elasticity. The basic intuition for this result is that adding the consumption-leisure choice allows the consumer to optimally adjust his labor supply in response to a change in real wage, whereas in standard trade models this choice is constrained. We then focus the analysis on a monopolistic competition setting a la Melitz (2003) (as formulated in Arkolakis et al. (2008)) where entry of firms is endogenous.<sup>5</sup> We show that, when the substitution effect is stronger than the income effect, the increase in labor supply induces additional entry of firms, which raises welfare due to gains from variety. These gains from variety are up to 65% of the total gains from trade. If instead the income effect dominates over the substitution effect, the decrease in labor brings down the entry of firms and thus leads to lower gains from trade than in ACR.

The model generates similar results also when we assume the existence of multiple sectors, in Section 3. We show that an Armington model with multiple sectors and elastic labor supply implies higher gains than a multiple sectors model featuring constant labor supply. Similarly to the baseline setting, with monopolistic competition and endogenous entry welfare gains are higher than ACR only if income effects are sufficiently small. Furthermore, due to the reallocation of labor across sectors, gains from trade are even bigger than in the baseline one sector model, as shown in Table 1.

Our welfare results do not depend on the separability between consumption and labor in the utility function. Indeed in Section 4 we show that our findings are virtually unchanged if instead we use a non-separable utility in consumption and leisure, where the elasticity of labor supply is no longer constant as in the baseline model. This strengthens our main result, since in the macro-labor literature relaxing the separability assumption can lead to different aggregate implications (see for example Basu and Kimball (2002) and Kimball and Shapiro (2008)).

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welfare gains would be very similar.

<sup>5</sup>Notice that a Melitz model with fixed entry, as in Chaney (2008), and an Eaton and Kortum (2002) model are isomorphic to the Armington model.

Motivated by the recent literature, we also consider a version of the model with variable markups, in Section 4. In particular, we use the same separable utility in consumption and labor as in the baseline model, but we assume that the consumption aggregator is a generalized CES over a continuum of varieties, similarly to Arkolakis et al. (2012a) (ACDR henceforth). In a setting characterized by monopolistic competition and endogenous entry, we show that when income effects are small, so that labor increases after an opening to trade, welfare gains are lower than ACDR and ACR. This result is driven by the distortion due to variable markups that triggers a reallocation of demand, and so of labor, toward less productive goods. In our model, the endogenous response of the labor supply can amplify this effect. If the total labor supplied increases after the rise in the real wage, more labor goes to less productive firms compared to a setting with fixed labor supply. This in turn implies that there is more misallocation of labor in the economy, leading to lower total welfare gains from trade. If instead the labor supply goes down, there is less labor misallocation across firms and gains are higher than ACDR.<sup>6</sup>

In the baseline model, we assume a separable utility in aggregate consumption and labor supply as in Mankiw et al. (1986), Domeij and Floden (2006) and Keane (2011), which has the logarithmic utility in consumption only as special case (when the risk aversion parameter  $\eta$  equals 1). One shortcoming of this formulation is that it is not consistent with a balanced growth path, as pointed out by King et al. (1988). While we acknowledge that reasons like innovations in leisure and changes in labor legislation may result in a labor supply roughly constant in the long run, the effects of trade are coming through the standard real wage mechanism studied by labor economists.<sup>7</sup> Given that empirical estimates of the labor supply elasticity suggest that the labor supply is responsive to changes in the real wage, we use the specification with  $\eta \neq 1$  so that income and substitution effects do not offset each other.

Our paper is closely related to quantitative trade models such as Eaton and Kortum (2002), Melitz (2003), Arkolakis et al. (2008), Arkolakis et al. (2012b) and Costinot and Rodríguez-Clare (2013). In contrast to these studies, we introduce endogenous labor supply in the context of a trade model and show how this affects the predictions for the welfare gains from trade. Previous studies have introduced elastic labor supply in trade models,

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<sup>6</sup>These results are somewhat in line with the findings of Edmond et al. (2012), that use the oligopolistic model with variable markups of Atkeson and Burstein (2008) to compute gains from trade. In the appendix to their paper they show that the relative importance of the pro-competitive effects is larger when the labor supply is elastic. This evidence suggests that elastic labor supply acts as an amplifying factor for the gains from trade, both in models where trade has pro-competitive effects (such as Edmond et al. (2012)) and models where trade increases distortions (such as ACDR).

<sup>7</sup>See Chetty (2012), Reichling and Whalen (2012), Keane (2011) among others.

but none has traced the link between labor supply and the gains from trade. Farhat (2009) studies the link between elastic labor supply and international correlation of business cycles and employment dynamics. Corsetti et al. (2007) have a trade model with endogenous labor supply, but their focus is on international prices movements and labor. Kemp and Jones (1962) and Mayer (1991) study endogenous labor supply and trade in a two-good small open economy environment. Martin (1976), Neary (1978), and Chen (1995) do so in a Heckscher-Ohlin framework.

It is worth noting that quantitative models of trade with monopolistic competition and inelastic labor supply typically feature a Pareto distribution of productivity. This assumption implies that, even with endogenous entry, the number of entrants is independent of trade costs, and thus gains from variety are absent. Instead, although we maintain the Pareto assumption, both labor supply and entry depend on trade and our model features gains (or losses) from variety due to trade liberalization.

Our model of endogenous labor supply does not predict the same gains as a setting with inelastic labor and a non-tradeable sector, as in Balistreri et al. (2010). In a model with a non-tradeable sector that linearly uses labor as factor of production, a trade liberalization simply induces a reallocation of labor toward the tradeable sector. In contrast, in our model if income effects are small then an increase in the real wage triggers an increase in the overall supply of labor, rising total income and shifting out the production possibility frontier (PPF) of the economy. More importantly, even if we consider parameters and functional forms so that the equilibrium allocations are the same in the two models, the equivalent variation, and thus the gains from trade, are nevertheless different. The reason is how the equivalent variation is computed in the two models: in a model with a non-tradeable sector, the income given to the consumer can be used to purchase both tradeable and non-tradeable goods, whereas in our model the agent is compensated only with tradeable consumption and not with additional leisure. Indeed, in the Appendix we show that in our framework welfare gains are always higher than in a model with a non-tradeable sector.

Our work is complementary to a strand of literature that studies the connection between labor markets and trade. Helpman et al. (2010) and Helpman and Itskhoki (2010) investigate the link between trade openness and unemployment, suggesting an ambiguous relationship between the two. Felbermayr et al. (2011) introduce search unemployment into the Melitz trade model, and show that in the long run trade openness lowers the rate of unemployment. Fajgelbaum (2013) develops a model to study the aggregate effects on firms decisions of labor market frictions in an open economy. While these papers focus on the link between trade

and the demand side of the labor market, our study concentrates explicitly on the supply side of the labor market and its link with welfare gains from trade.

Finally, the empirical literature provides scarce evidence about the relationship between trade policy and aggregate labor supply.<sup>8</sup> It is indeed a difficult task to empirically identify a trade shock from other policy and technological shocks that affect real wages and thus labor supply in the long run. Although this could be an avenue for future research, such evidence is not necessary to gauge the relevance of our theoretical contribution. Since empirical estimates of the labor elasticity suggest that labor supply responds to both short and long run shocks to the real wage, then a trade policy that affects the real wage must have an impact also on the labor supply. In addition, we show that even if the endogenous response of labor supply to a trade liberalization is small, it induces considerable variety effects that amplify the gains from trade.

This paper is structured as follows: in Section 2 we show the baseline model under the Armington and Melitz market environments; in Section 3 we study the quantitative implications of the model, computing the welfare gains for a set of countries; in Section 4 we explore extensions of our main results, such as a setting with endogenous markups and then one with non-separable preferences; Section 5 concludes and discusses avenues for future research.

## 2 A Model with elastic labor supply

We consider a model with  $N$  countries, where production occurs with only one factor, labor, provided elastically by one representative consumer and immobile across countries. We assume the existence of iceberg trade barriers  $\tau_{ij} \geq 1$  for shipping a good from country  $i$  to country  $j$ , and normalize domestic trade barriers, so that  $\tau_{ii} = 1$ .

### 2.1 Consumer side

In our baseline specification for the representative consumer we assume that the utility is given by

$$U_j(C_j, L_j) = \frac{C_j^{1-\eta}}{1-\eta} - \frac{L_j^{1+\frac{1}{\varepsilon}}}{1+\frac{1}{\varepsilon}}, \quad \eta \neq 1 \quad (1)$$

where  $C_j$  is a consumption aggregator,  $L_j$  is labor supplied and  $\varepsilon > 0$  is the Frisch elasticity

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<sup>8</sup>See Blundell and MaCurdy (1999) for an analysis of empirical trends in hours worked and participation rates.

of labor. The appealing feature of this functional form is that the parameter  $\varepsilon$  is an upper bound for the substitution effect, while  $\eta$  regulates the magnitude of the income effect.<sup>9</sup> We assume that  $C_j$  is given by a Constant Elasticity of Substitution (CES) aggregator over a continuum of goods  $\omega$ :

$$C_j \equiv \left( \sum_i \int_{\omega \in \Omega_{ij}} c_{ij}(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}}, \quad (2)$$

$c_{ij}(\omega)$  is the consumption of good  $\omega$  produced in country  $i$  and sold in country  $j$ , and  $\sigma$  is the elasticity of substitution between goods. Given prices  $p_{ij}(\omega)$  and wages  $w_j$ , the consumer maximizes equation (1) subject to the budget constraint:

$$\sum_i \int_{\omega \in \Omega_{ij}} p_{ij}(\omega) c_{ij}(\omega) d\omega \leq w_j L_j. \quad (3)$$

This utility specification has been used by Mankiw et al. (1986), Domeij and Floden (2006), Corsetti et al. (2007) and Keane (2011) among others. In the extreme case of  $\eta = 0$ , income effects are completely shut down and thus labor is increasing in real wage, while if  $\eta > 1$  the income effect dominates the substitution effect and labor supply is decreasing in the real wage. The limiting case of  $\eta = 1$  is often used in the macro literature, such as Kimball and Shapiro (2008), Shimer (2009) and Ohanian and Raffo (2012), because in this way preferences are consistent with a balanced growth path (BGP). We use instead the specification  $\eta \neq 1$  since it implies that the income and substitution effects do not exactly offset each other, and thus, in accordance with empirical estimates, labor supply is responsive to a change in the real wage. In the robustness section we show that if we rescale the utility to be consistent with a BGP, as in Mertens and Ravn (2011), the welfare gains are virtually the same as in the baseline model.

Using the necessary first order conditions associated with the maximization problem, it is straightforward to show that the optimal choices for consumption and labor are, respectively,

$$c_{ij}(\omega) = \frac{p_{ij}(\omega)^{-\sigma}}{P_j^{1-\sigma}} w_j L_j, \quad (4)$$

and

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<sup>9</sup>See Keane (2011) and Chetty (2012).

$$L_j = \left( \frac{w_j}{P_j} \right)^{\frac{\varepsilon(1-\eta)}{1+\eta\varepsilon}}, \quad (5)$$

where  $P_j$  is the CES price index:

$$P_j = \left( \sum_i \int_{\omega \in \Omega_{ij}} p_{ij}(\omega)^{1-\sigma} d\omega \right)^{\frac{1}{1-\sigma}}. \quad (6)$$

Finally, the CES demand system implies that aggregate consumption is equal to real income:

$$C_j = \frac{w_j}{P_j} L_j. \quad (7)$$

We next turn to the production side of the economy which we model in two different ways, with and without variety effects.

## 2.2 Production side - Armington model

We start by considering a simple Armington framework (Armington (1969)), which does not feature variety effects. In this setting there are  $N$  countries, each producing a differentiated good one-to-one from labor, sold at its marginal cost. The price index is simply:

$$P_j = \left( \sum_i (w_i \tau_{ij})^{1-\sigma} \right)^{\frac{1}{1-\sigma}}, \quad (8)$$

and the value of country  $j$  total imports from country  $i$  is:

$$X_{ij} = \left( \frac{w_i \tau_{ij}}{P_j} \right)^{1-\sigma} Y_j,$$

where  $Y_j = \sum_i X_{ij}$  is total expenditure in country  $j$ .

### 2.2.1 Trade equilibrium and Welfare

We now describe the equations that define the trade equilibrium in our model. Labor market clearing implies

$$w_j L_j = \sum_i \lambda_{ij} w_i L_i, \quad (9)$$

where  $\lambda_{ij}$  are the trade shares given by:



$$\lambda_{ij} \equiv \frac{X_{ij}}{\sum_i X_{ij}} = \frac{(w_i \tau_{ij})^{1-\sigma}}{\sum_i (w_i \tau_{ij})^{1-\sigma}}. \quad (10)$$

Notice that the constant elasticity gravity structure of ACR is retained intact. Setting  $i = j$  in the gravity equation, solving for  $w_j$  and substituting out the definition of the price index in Equation (8), we obtain an expression for the real wage:

$$\frac{w_j}{P_j} = (\lambda_{jj})^{\zeta_A}, \quad (11)$$

where  $\zeta_A = 1/(1 - \sigma)$ . The relationship between real wage and trade in this model is the same as in a standard trade model.

The equilibrium in this economy is characterized by a vector of wages  $\{w_i\}$ , and labor choices  $\{L_i\}$  that solve the system of equations (5) and (9) where  $\lambda_{ij}$  is given by equation (10). Following Alvarez and Lucas (2007), in the Appendix we prove that uniqueness of the equilibrium requires the sufficient condition:

$$\sigma > 1 + \frac{\varepsilon(1 - \eta)}{1 + \eta\varepsilon}, \quad (12)$$

which is assumed to hold throughout the paper.<sup>10</sup> Having completed the derivation of the equilibrium, we now turn to the welfare analysis of a trade liberalization. We consider a change in variable trade costs from  $\tau \equiv \{\tau_{ij}\}$  to  $\tau' \equiv \{\tau'_{ij}\}$ . The equivalent variation associated with this change in trade costs,  $e_j(p_{ij}, \bar{u}_j')$ , is the amount of expenditure, evaluated at initial prices, required to reach the utility of the counterfactual equilibrium and is expressed as a percentage of the income of the representative agent:<sup>11</sup>

$$\hat{W} = \frac{e_j(p_{ij}, \bar{u}_j') - e(p_{ij}, \bar{u}_j)}{e(p_{ij}, \bar{u}_j)} = \frac{e_j(p_{ij}, \bar{u}_j') - w_j L_j}{w_j L_j}. \quad (13)$$

We denote with a hat the ratio of the counterfactual to the initial variables, i.e.  $\hat{x}_j \equiv x'_j/x_j$ . Our first result characterizes the welfare gains from trade in the Armington model with elastic labor supply (all the relevant proofs of the paper are relegated in the Appendix):

**Proposition 1.** *In a model with elastic labor supply and perfect competition, the welfare*

<sup>10</sup>In models with inelastic labor supply, the condition for uniqueness is instead  $\sigma > 1$ . See Allen et al. (2014).

<sup>11</sup>Using the notion of compensating variation would produce similar results. We use the equivalent variation instead because it does not require knowledge of the counterfactual prices, which facilitates the analytical and empirical analysis.

*gains from trade are:*

$$\hat{W}_j = \left( \hat{\lambda}_{jj} \right)^{\varphi_A} \left[ 1 - \frac{\varepsilon(1-\eta)}{1+\varepsilon} \left( 1 - \left( \hat{\lambda}_{jj} \right)^{-\varphi_A(1-\eta)} \right) \right]^{\frac{1}{1-\eta}} - 1, \quad (14)$$

where  $\varphi_A \equiv \zeta_A \frac{(1+\varepsilon)}{(1+\eta\varepsilon)} < 0$ . Moreover, welfare gains are always higher than in a model with inelastic labor supply.

Proposition 1 shows that the gains from trade in our model with elastic labor supply are higher than in the class of models considered by ACR. Notice that this results holds independently if the labor increases or decreases with a trade liberalization (which happens respectively, with  $\eta > 1$  and  $\eta < 1$ ). Moreover, it shows that the welfare analysis can be conducted using only a few sufficient statistics. In particular, the change in the share of expenditure on domestic goods,  $\hat{\lambda}_{jj}$ , is the only endogenous variable needed to be observed in order to evaluate the welfare impact of a change in trade barriers. The parameter  $\varepsilon$  is simply the Frisch elasticity of labor supply, for which many empirical estimates are available (see Prescott and Wallenius (2012); Reichling and Whalen (2012)). Moreover we choose the value of  $\eta$  to match the model's compensated elasticity of labor:

$$\theta^c = \frac{\varepsilon}{1 + \eta\varepsilon}, \quad (15)$$

with estimates of this elasticity available from the empirical labor literature (see Chetty (2012)).<sup>12</sup>

To gain more intuition from the formula in Proposition 1, we can re-arrange it for the limit case of  $\eta = 0$ :

$$\hat{W}_j = \underbrace{\left( \hat{\lambda}_{jj} \right)^{\frac{1}{1-\sigma}}}_{\text{ACR}} \underbrace{\left( \frac{L'_j}{L_j} \right)}_{\text{supply effect}} - \underbrace{\frac{\varepsilon}{1+\varepsilon} (\lambda_{jj})^{\frac{1+\varepsilon}{\sigma-1}} \left( L_j'^{1+1/\varepsilon} - L_j^{1+1/\varepsilon} \right)}_{\text{leisure effect}} - 1. \quad (16)$$

Equation (16) illustrates that the gains from trade can be decomposed in three terms: a term which represents the ACR gains from trade; a supply effect which reflects the increase (since  $\eta = 0$ ) in total labor supply and thus the upward shift of the PPF of the economy; a negative term consisting in the increase in the loss of leisure in the utility, multiplied by the inverse of the initial real income,  $(\lambda_{jj})^{\frac{\varepsilon+1}{\sigma-1}}$ . This last term reflects the fact that there is

<sup>12</sup>As discussed in the quantitative section, we could also use estimates of the uncompensated elasticity from Evers et al. (2008), with similar results.

a certain utility loss due to the decrease in leisure, but this effect is decreasing in the level of initial income: an economy that starts with a low level of income is affected more by the loss in leisure, due to the concavity of the utility function. Notice that when  $\eta > 1$  the mechanisms at play are the same, but reversed: since  $L'_j < L_j$  because income effects are big, the leisure effect increases gains from trade, while the supply effect lowers them.

We now turn the analysis to the monopolistic competition case with endogenous entry, which delivers richer implications for the gains from trade.

### 2.3 Production side - Melitz model

To study the effect of variety with endogenous labor supply we next consider a version of the Melitz (2003) monopolistic competition model with firm heterogeneity and endogenous entry. Each firm can choose to pay an entry cost  $f_e$ , and upon entry learns its productivity  $z$  from a pre-specified distribution. We denote the measure of equilibrium entrants as  $J_i$ . In order to export the firm has to incur iceberg costs, as before, but also an additional fixed exporting cost  $f_{ij}$ , in terms of foreign labor.

Given CES consumer demand, the maximization problem of a firm with productivity  $z$  is

$$\pi_{ij}(z) = \max_{p_{ij}(z)} \left\{ \frac{p_{ij}(z)^{1-\sigma}}{P_j^{1-\sigma}} w_j L_j - \frac{p_{ij}(z)^{-\sigma}}{P_j^{1-\sigma}} w_j L_j \frac{\tau_{ij} w_i}{z} - w_j f_{ij} \right\},$$

where  $z$  is the firm productivity draw. The optimal price is a constant markup over the marginal cost:

$$p_{ij}(z) = \frac{\sigma}{\sigma - 1} \frac{\tau_{ij} w_i}{z}. \quad (17)$$

This result implies that bilateral sales of a firm  $z$  from country  $i$  to  $j$  are

$$y_{ij}(z) = \left( \frac{\sigma}{\sigma - 1} \frac{\tau_{ij} w_i}{z} \right)^{1-\sigma} \frac{w_j L_j}{P_j^{1-\sigma}}, \quad (18)$$

and profits are a share  $1/\sigma$  of sales. If we equate marginal profit to fixed costs and substitute for the optimal labor choice, we can solve for the threshold productivity cutoff of entry for firms from country  $i$  selling to country  $j$ :

$$(z_{ij}^*)^{\sigma-1} \equiv \frac{f_{ij} \sigma (P_j)^{\frac{(1+\eta\varepsilon)(1-\sigma)+\varepsilon(1-\eta)}{1+\eta\varepsilon}}}{\left( \frac{\sigma}{\sigma-1} \tau_{ij} w_i \right)^{1-\sigma} (w_j)^{\frac{\varepsilon(1-\eta)}{1+\eta\varepsilon}}}. \quad (19)$$

Using these solutions we proceed to compute the trade equilibrium and the associated gains from trade.

### 2.3.1 Trade equilibrium and Welfare

We specify the distribution of firm productivities following Helpman et al. (2004), Chaney (2008) and Arkolakis et al. (2008). In particular, we assume that the productivity of firms in country  $i$  is drawn from a Pareto distribution with density:

$$g(z) = \theta z^{-\theta-1}, \quad z \geq 0 \quad (20)$$

with shape parameter  $\theta > 0$ . In this market setting the price index is:

$$P_j^{1-\sigma} = \sum_i J_i \int_{z_{ij}^*}^{\infty} \left( \frac{\sigma}{\sigma-1} \frac{\tau_{ij} w_i}{z} \right)^{1-\sigma} \theta z^{-\theta-1} dz. \quad (21)$$

In order to solve for equilibrium wages,  $w_i$ , and the number of entrants,  $J_i$ , we use the labor market clearing condition and the zero-profit condition. The first gives us:

$$J_i \sum_j \int_{z_{ij}^*}^{\infty} \tau_{ij} \left( \frac{\sigma}{\sigma-1} \tau_{ij} w_i \right)^{-\sigma} \frac{w_j L_j}{P_j^{1-\sigma}} \theta z^{\sigma-\theta-2} dz + J_i f_e + \sum_j J_j \int_{z_{ji}^*}^{\infty} f_{ji} \theta z^{-\theta-1} dz = L_i, \quad (22)$$

which states that in each country the supply of labor must equal the amount of labor used for production, to pay the entry cost and the fixed cost of production. Expected profits in equilibrium are zero so that

$$\sum_j \int_{z_{ij}^*}^{\infty} \left( \frac{\sigma}{\sigma-1} \tau_{ij} w_i \right)^{1-\sigma} \frac{w_j L_j}{\sigma P_j^{1-\sigma}} \theta z^{\sigma-\theta-2} dz - \sum_j \int_{z_{ij}^*}^{\infty} w_j f_{ij} \theta z^{-\theta-1} dz = w_i f_e. \quad (23)$$

In the Appendix we use equations (21), (22) and (23) to show that the number of entrants  $J_i$  is proportional to the labor endogenously supplied:

$$J_i = \frac{\sigma-1}{\sigma \theta f_e} L_i, \quad (24)$$

similarly to Arkolakis et al. (2008).<sup>13</sup> Intuitively, an increase in labor after a rise in the real wage induces an increase of the demand, pushing up expected profits and thus stimulating

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<sup>13</sup>To solve for the integrals, we make the standard assumption that  $\theta > \sigma - 1$ .

more entry of firms. Finally, trade shares are given by:

$$\lambda_{ij} = \frac{J_i \int_{z_{ij}^*} y_{ij}(z) \theta z^{-\theta-1} dz}{\sum_k J_k \int_{z_{kj}^*} y_{kj}(z) \theta z^{-\theta-1} dz} = \frac{f_{ij}^{\frac{1-\sigma+\theta}{1-\sigma}} L_i(\tau_{ij} w_i)^{-\theta}}{\sum_k f_{kj}^{\frac{1-\sigma+\theta}{1-\sigma}} L_k(\tau_{kj} w_k)^{-\theta}}, \quad (25)$$

and depend crucially on labor supply decisions. Notice that the gravity equation is the same as in ACR, and the partial trade elasticity, as in their case, is simply  $-\theta$ .<sup>14</sup>

The equilibrium in this economy is characterized by a vector of wages  $\{w_i\}$ , price indexes  $\{P_i\}$  and labor choices  $\{L_i\}$  such that the system of equations (5), (21) and (22) is solved. It is worth noting that, as shown by Bilbiie et al. (2008), the competitive equilibrium is not efficient, in the sense that it does not reach the same allocations of the social planner problem. The reason is that the markup creates a wedge between the marginal rate of substitution between consumption and leisure and the marginal rate of transformation between labor supply and consumption. Intuitively, since consumption goods are priced at a markup while leisure is not, demand for the latter is sub-optimally high, and hence hours worked and consumption are sub-optimally low.<sup>15</sup>

The Appendix shows that the real wage can be written as a function of domestic trade shares:

$$\frac{w_j}{P_j} = \vartheta_{jj}^{\zeta_M} \lambda_{jj}^{\zeta_M}, \quad (26)$$

where  $\zeta_M \equiv \frac{(1+\eta\varepsilon)(\sigma-1)}{\theta(1+\varepsilon-\sigma(1+\eta\varepsilon))} < 0$  because of Equation (12) and  $\vartheta_{jj} > 0$  is a constant.<sup>16</sup> Notice that when  $\varepsilon = \eta = 0$ , the real wage is the same as in ACR, namely,  $w_j/P_j = \vartheta_{jj}^{-\frac{1}{\theta}} \lambda_{jj}^{-\frac{1}{\theta}}$ .

Having completed the derivation of the equilibrium, we characterize the welfare gains for the Melitz model in the following proposition:

**Proposition 2.** *In a model with elastic labor supply and monopolistic competition, the welfare gains from trade are:*

$$\hat{W}_j = \left( \hat{\lambda}_{jj} \right)^{\varphi_M} \left[ 1 - \frac{\varepsilon(1-\eta)}{1+\varepsilon} \left( 1 - \left( \hat{\lambda}_{jj} \right)^{-\varphi_M(1-\eta)} \right) \right]^{\frac{1}{1-\eta}} - 1, \quad (27)$$

<sup>14</sup>Recall that the partial trade elasticity is defined as  $\frac{\partial \ln(\lambda_{ij}/\lambda_{jj})}{\partial \ln \tau_{ij}}$ . See ACR and Melitz and Redding (2013).

<sup>15</sup>Bilbiie et al. (2008) also prove that this distortion can be removed by taxing leisure at a rate equal to the net markup in the pricing of goods, because it ensures effective markup synchronization.

<sup>16</sup>In particular,  $\vartheta_{jj} \equiv f_{jj}^{\frac{\sigma-\theta-1}{1-\sigma}} f_e^{\frac{\theta-\sigma+1}{\sigma-1}} \left( \frac{\sigma}{\sigma-1} \right)^\theta \sigma^{\frac{\theta}{\sigma-1}}$ . Notice that this constant is the same as in Arkolakis et al. (2008).

where  $\varphi_M \equiv \zeta_M \frac{(1+\varepsilon)}{(1+\eta\varepsilon)} < 0$ . Moreover, if  $\eta < 1$  the gains are higher than in a model with inelastic labor supply.

With monopolistic competition there is an additional channel at play: the entry of new firms. If the substitution effect dominates over the income effect, which happens only when  $\eta < 1$ , then the increase in labor supply induces a boost in the entry of firms, which leads to higher welfare due to bigger gains from variety. In contrast, if  $\eta > 1$  labor supply decreases after the initial increase in the real wage, and this causes many firms to go out, inducing negative gains from variety. In addition, since the aggregate hours worked are lower, total income gains are lower, reducing the total gains from trade to less than in a model with fixed labor supply. Similarly to the Armington model, assuming  $\eta = 0$  for simplicity we can decompose the welfare gains:

$$\hat{W}_j = \underbrace{\left(\hat{\lambda}_{jj}\right)^{-\frac{1}{\theta}}}_{\text{ACR}} \underbrace{\left(\hat{\lambda}_{jj}\right)^{\frac{\varepsilon}{\theta(1+\varepsilon-\sigma)}}}_{\text{entry effect}} \underbrace{\left(\frac{L'_j}{L_j}\right)}_{\text{supply effect}} - \underbrace{\frac{\varepsilon}{1+\varepsilon} (\vartheta \lambda_{jj})^{\frac{(\sigma-1)(1+\varepsilon)}{\theta(1+\varepsilon-\sigma)}} \left(L_j^{1+1/\varepsilon} - L_j^{1+1/\varepsilon}\right)}_{\text{leisure effect}} - 1. \quad (28)$$

Compared to the Armington case with fixed number of varieties, in Equation (28) there is the additional entry effect term, which further increases welfare gains.

In order to illustrate how gains from trade differ in our model from ACR, we perform a simple numerical simulation. In particular, we consider for simplicity two symmetric countries and assume that they move from trade costs of  $\tau_{ij} = 1.1$  to free trade. We then compare the welfare gains predicted by ACR with the ones implied by our model, for both the Armington and Melitz settings.<sup>17</sup> We pick  $\varepsilon$  to capture a range of different Frisch elasticities, which go from 0-0.4 of micro-based estimates to 1-2 of macro-based estimates.<sup>18</sup> We choose  $\eta$  between 0 and 1.5 to capture different magnitudes of the income effect, and set the trade elasticity to 4 as estimated by Simonovska and Waugh (2014).<sup>19</sup>

Figure 1 plots the change in labor supply: in both models the optimal labor supply increases if  $\eta < 1$ , but with endogenous entry (Melitz) the increase in labor is higher since labor is an increasing function of real wage, which in turns depends on entry. Figure 2 illustrates the findings of Proposition 1 and 2: in the Armington model welfare gains are

<sup>17</sup>Since countries are symmetric, the change in domestic trade shares,  $\hat{\lambda}_{jj}$ , is the same in the two models.

<sup>18</sup>See Reichling and Whalen (2012).

<sup>19</sup>Notice that to have a trade elasticity of 4 in the Armington model we have to set  $\sigma = 5$ , while in the Melitz model we have to set  $\theta = 4$  and  $\sigma = 4$ , to be consistent with the usual condition that  $\theta > \sigma - 1$ .

always higher than ACR and converge to that when  $\varepsilon$  tends to zero, while in the Melitz model gains are higher when  $\eta < 1$ . In addition, Figure 3 shows that in the Melitz setting gains from variety can account for up to 65% of the total gains from trade, suggesting the relevance of this channel.

Lastly, we have explored whether the welfare results are robust to the functional form we have assumed. In particular, in the robustness section of the Appendix we show that the findings are virtually unchanged if we assume a separable utility rescaled to be consistent with a balanced growth path and with an upper bound on labor (see Mertens and Ravn (2011)). In addition, we show that a simple model with fixed labor supply but with a non-tradeable sector, does not predict the same gains from trade as our model with endogenous labor supply.

In the following section we explore the quantitative implications of endogenous labor supply in a multi-country calibrated version of our model.

### 3 Quantitative implications

To evaluate the predictions of our model we focus on an instructive counterfactual exercise: moving to autarky. In particular, we evaluate the welfare changes associated with moving a country from the observed trade equilibrium to a counterfactual equilibrium without trade.<sup>20</sup> Since the share of expenditure on domestic goods is equal to 1 in the counterfactual equilibrium, we know that  $\hat{\lambda}_{jj} = 1/\lambda_{jj}$ . We set the trade elasticity to 4 in both Armington and Melitz one sector models, consistently with Simonovska and Waugh (2014). In order to measure  $\lambda_{jj}$  in the data, note that  $\lambda_{jj} = 1 - \frac{\sum_{i \neq j} X_{ij}}{\sum_i X_{ij}}$ , where we can measure  $\sum_{i \neq j} X_{ij}$  as total imports by country  $j$  and  $\sum_i X_{ij}$  as total expenditure by country  $j$ . We use data from the World Input-Output Database (WIOD) in 2008, which covers 40 major countries; see Costinot and Rodríguez-Clare (2013) and Dietzenbacher et al. (2013).

Furthermore, to exploit more the richness of the data we calibrate a multiple sectors version of our model, for both the Armington and Melitz settings. In particular, we assume that total consumption  $C_j$  is a Cobb-Douglas aggregator of sectoral consumption bundles  $C_j^s$ :

$$C_j = \prod_{s=1}^S (C_j^s)^{\gamma_j^s},$$

where  $0 < \gamma_j^s \leq 1$  are the consumption shares and are such that  $\sum_{s=1}^S \gamma_j^s = 1$ . In the

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<sup>20</sup>Formally, we follow Costinot and Rodríguez-Clare (2013) and define gains from trade as the absolute value of the equivalent variation associated with moving to autarky.

Appendix we show that with multiple sectors the gains from trade can be written as:

$$\hat{W}_j = (\hat{\kappa}_{jj})^{\varphi_S} \left[ 1 - \frac{\varepsilon(1-\eta)}{1+\varepsilon} \left( 1 - (\hat{\kappa}_{jj})^{-\varphi_S(1-\eta)} \right) \right]^{\frac{1}{1-\eta}} - 1, \quad (29)$$

where  $\varphi_S \equiv \frac{(1+\varepsilon)}{1+\eta\varepsilon}$ ,  $\kappa_{jj} \equiv \prod_{s=1}^S (\lambda_{jj}^s)^{\frac{\gamma_j^s}{1-\sigma}}$  in Armington, while  $\kappa_{jj} \equiv \prod_{s=1}^S (\vartheta_{jj}^s \lambda_{jj}^s)^{\zeta^s \gamma^s}$  in Melitz.<sup>21</sup> We also show that with Armington gains are always higher than the multi-sector version of ACR, while in Melitz gains are higher only if  $\eta < 1$ .

In the calibration, we use data on sectoral trade elasticities and sectoral consumption shares from Caliendo and Parro (2012). The parameter  $\varepsilon$  is the Frisch elasticity, for which an extensive number of micro and macro estimates exist.<sup>22</sup> To calibrate the parameter  $\eta$ , we match the model compensated elasticity, given by equation (15), with estimates of the aggregate Hicksian elasticity (extensive plus intensive margin) of 0.50, from Chetty (2012).<sup>23</sup> Given that the Frisch elasticity cannot be much larger than the Hicksian elasticity for plausible values of the income effect (see for example Table III in Chetty (2012)), this suggests a reasonable range for  $\varepsilon$  of 0.5 – 0.8, consistent with the evidence in Reichling and Whalen (2012).<sup>24</sup> Using equation (15), this implies a range for  $\eta$  of 0 – 0.75. Therefore we report the results for  $\eta = 0.1$  and  $\eta = 0.5$ , in Table 1 and 3 respectively.

The first column of both Table 1 and 3 reports the gains from trade for the Armington version of our model, using Equation (14), whereas the second column reports the gains for the Melitz model, using Equation (27). In addition, the third column simply reports the gains from trade in the ACR model. Since we calibrate the Melitz and Armington models to have the same trade elasticity, ACR predicts the same gains for the two models. The last three columns instead refer to the multiple sectors version of our model and ACR. We can see that our model implies higher gains than ACR for all countries in the sample, and that the difference is bigger for the Melitz model, due to the entry effect. In particular, in Table 1, with  $\eta = 0.1$ , in the one sector Melitz model the median country has gains of 6.82%, compared to 5.69% in ACR. In the multi-sector Melitz model instead the median country has welfare gains of 18.06% versus 14.66% of ACR, with a peak of 66% for a small country

<sup>21</sup>The constants are  $\zeta^s \equiv \frac{(1+\eta\varepsilon)(\sigma-1)}{\theta^s(1+\varepsilon-\sigma(1+\eta\varepsilon))}$  and  $\vartheta_{jj}^s \equiv f_{jj}^{\frac{\sigma-\theta^s-1}{1-\sigma}} f_e^{\frac{\theta^s-\sigma+1}{(\sigma-1)}} \left( \frac{\sigma}{\sigma-1} \right)^{\theta^s} \sigma^{\frac{\theta^s}{\sigma-1}}$ .

<sup>22</sup>See the survey in Reichling and Whalen (2012).

<sup>23</sup>We could also use estimates of the uncompensated elasticity from Evers et al. (2008), with similar results.

<sup>24</sup>Intuitively, the Frisch elasticity cannot be much larger than the Hicksian elasticity for plausible values of the income effect because  $\varepsilon^{hicks} - \varepsilon^{frisch}$  is proportional to the income effect squared times the ratio of assets to earnings, which is not very high for most households in the United States. See equation 22 in Chetty (2012) and Dynan (2009).



such as Belgium.

As Table 2 indicates, in all calibrations labor supply increases with trade, given that  $\eta < 1$ . In particular, in the Armington model changes in labor supply are relatively small. With endogenous entry, instead, labor supply effects are larger and induce sizeable increases in gains from trade. Still, the median country experiences large gains from trade but the increase in labor supply is up to only 7.86%.

In Table 3, with  $\eta = 0.5$ , gains in our model are still higher than ACR, but the difference is smaller than in the case  $\eta = 0.1$ . The reason is that the higher  $\eta$ , the stronger the income effect on labor supply and thus the impact of the supply effect on the gains is smaller. However, in our model the average country still experiences gains from trade up to 13% higher than ACR. Furthermore, it is interesting to notice that smaller countries not only have higher welfare gains than larger countries, consistent with basic insights from trade theory, but also higher additional gains due to the labor supply effect.

Finally, in Table 4 we decompose the gains from trade for the one sector Melitz model in leisure effect, supply effect and entry effect, using Equation (28). The results show that for all countries the supply and entry effects have the same magnitudes, and that gains in ACR are around 50% of the total gains from trade.

## 4 Extensions

In this section we explore extensions of the general results. Motivated by the existing literature, we study first a setting with endogenous markups and then a model with non-separable preferences.

### 4.1 Variable markups

In this section we verify, following Arkolakis et al. (2012a) (ACDR henceforth), whether relaxing the constant markup assumption can lead to substantially different gains from trade. For this reason we assume the same separable utility in consumption and labor as in the baseline model, but now aggregate consumption  $C_j$  is a generalized CES utility function defined over a continuum of goods:

$$C_j \equiv \left( \sum_i \int_{\omega \in \Omega_{ij}} (q_\omega + \bar{c})^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}},$$

with  $\bar{c} > 0$ . This functional form has the advantage of being very similar to the baseline

utility, since it converges to the CES case for  $\bar{c} = 0$ .<sup>25</sup> This simple modification of the CES aggregator implies that the reservation price is no longer infinity, and thus some goods are not consumed in equilibrium.<sup>26</sup> The optimal quantities are given by:

$$q_\omega = \bar{c} \left( \left( \frac{p_\omega}{p_j^*} \right)^{-\sigma} - 1 \right), \quad (30)$$

$$L_j = \left( \frac{1}{P_j} \right)^{(1-\sigma\eta)\varepsilon} \left( \frac{w_j}{\bar{c}^\eta} \right)^\varepsilon (p_j^*)^{-\sigma\eta\varepsilon}, \quad (31)$$

where the choke price  $p_j^* < \infty$  is the lowest price such that the quantity demanded is zero, and  $P_j \equiv \left( \sum_i \int_{\omega \in \Omega_{ij}} p_\omega^{1-\sigma} d\omega \right)^{\frac{1}{1-\sigma}}$  is the price index.<sup>27</sup>

Moreover, we follow ACDR and assume that firms compete under monopolistic competition, entry is endogenous and productivities are Pareto distributed, as in baseline specification. In addition, there are no fixed costs of accessing domestic and foreign markets. Since there is separability between consumption and labor in the utility function, the optimal markup is the same as in ACDR, and it is increasing in the productivity of the firm. The selection of firms across markets is driven entirely by the choke price  $p_j^*$ . In particular, a firm from  $i$  enters a market  $j$  if and only its productivity  $z$  is higher than a cutoff  $z_{ij}^* \equiv \frac{w_i \tau_{ij}}{p_j^*}$ .

It is easy to show, using the trade balance condition (9) and the following labor market clearing condition:

$$J_i \sum_j \int_{z_{ij}^*}^{\infty} \frac{\tau_{ij}}{z} q_{ij}(z) \theta z^{-\theta-1} dz + J_i f_e = L_i, \quad (32)$$

that the number of firms is:

<sup>25</sup>Simonovska (2010) uses the same specification.

<sup>26</sup>Notice that in the CES utility case the reservation price is infinity, which implies that the consumer always consumes any good, regardless of how expensive a good is.

<sup>27</sup>We derive the choke price in a simple way. From the FOC for  $q_\omega$  :

$$q_\omega = \left( \int (q_\omega + \bar{c})^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{(1-\eta\sigma)\sigma}{\sigma-1}} (\lambda p_\omega)^{-\sigma} - \bar{c}$$

impose  $q_\omega = 0$  and solve for the price:

$$p_\omega^* = \lambda^{-1} \bar{c}^{-1/\sigma} \left( \int (q_\omega + \bar{c})^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{(1-\eta\sigma)}{\sigma-1}}$$

Note that this price is the same across all goods, so we define it as  $p^*$ . It is a “choke price” because if  $p_\omega > p^*$ , then  $q_\omega = 0$ .

$$J_j = \chi L_j, \quad (33)$$

where  $\chi$  is a positive constant.<sup>28</sup> Since  $J$  is proportional to labor, which moves endogenously with wages and choke price, the number of firms is no longer constant as in ACDR. This implies that entry matters for the gains from trade, and affects trade shares as well:

$$\lambda_{ij} = \frac{L_i(w_i\tau_{ij})^{-\theta}}{\sum_k L_k(w_k\tau_{kj})^{-\theta}}. \quad (34)$$

However notice that, even with a non-CES utility, the partial trade elasticity is simply  $-\theta$ , as in ACR and ACDR. The trade equilibrium in this economy is characterized by a vector of wages  $\{w_i\}$ , choke prices  $\{p_i^*\}$  and labor choices  $\{L_i\}$  such that the system of equations (9), (31) and (32) is solved.

In this case, we cannot obtain an analytical expression for the equivalent variation only as a function of observed variables. Nevertheless, we can compute the percentage change in the expenditure following a small change in trade costs.<sup>29</sup> In the Appendix we show that differentiating the “excess” expenditure function and assuming symmetric countries, the percentage change in the expenditure can be written as:

$$d\ln e_j = \underbrace{\frac{d\ln\lambda_{jj}}{\theta}}_{\text{ACR}} - \underbrace{\frac{\rho}{1+\theta} \frac{d\ln\lambda_{jj}}{\theta}}_{\text{markup distortion}} + \underbrace{\frac{\sigma\eta\varepsilon\theta}{1+\theta} V_j \frac{d\ln\lambda_{jj}}{\theta}}_{\text{entry/labor supply effect}} + \underbrace{(1-\sigma\eta)\varepsilon V_j d\ln P_j}_{\text{labor distortion}}, \quad (35)$$

where  $V_j > 0$  is the average utility that the consumer gets from an additional variety and  $\rho$  is the average markup elasticity across all firms, as in ACDR. The above formula has four terms: the first is the percentage change in expenditure in ACR; the second term represents the distortion brought by variable markups, as in ACDR; the third term is the effect of the change in total labor supply and thus in entry; the last term reflects the interaction between elastic labor supply and variable markups. As shown in ACDR, there is a distortion due to variable markups that triggers a reallocation of demand, and so of labor, toward less productive goods. In our model, the endogenous response of the labor supply can amplify this effect, affecting the magnitude of the gains from trade.

<sup>28</sup>See ACDR for a complete derivation of the equation (33).

<sup>29</sup>Recall that both in ACR and ACDR the welfare gains from trade are simply the negative of the percentage change in the expenditure.

To quantify this channel, we consider two symmetric countries and numerically compute the gains from trade after a decrease in 10% of trade costs in our model with generalized CES demand, and compare them with ACR and ACDR.<sup>30</sup> We run this exercise for different values for  $\varepsilon$  and  $\eta$ ; we set  $\bar{c} = 0.5$  and as before the trade elasticity to 4. Figure 4 shows that the gains from trade in our model are lower than ACR and ACDR when  $\eta < 1$ , while they are higher when  $\eta > 1$ . Notice that this finding is exactly the opposite of what we have found in the baseline CES model. When  $\eta < 1$ , the total labor supplied increases after the rise in the real wage, and thus more labor goes to less productive firms compared to a setting with fixed labor supply. This in turn implies that there is more misallocation of labor in the economy, leading to lower total welfare gains from trade. If instead  $\eta > 1$ , labor supply goes down, there is less labor misallocation across firms and gains are higher than ACDR.

Our results are somewhat in line with the findings of Edmond et al. (2012). In the appendix to their paper they show that introducing elastic labor supply in their oligopolistic model with variable markups increases pro-competitive effects of trade. This evidence suggests that elastic labor supply acts as an amplifying factor for the gains from trade, both in models where trade has pro-competitive effects (such as Edmond et al. (2012)) and models where trade increases distortions (such as ACDR).

## 4.2 Non-separable preferences

We finally consider whether separability between consumption and leisure matters for our welfare results. We assume that there is a certain degree of substitutability in the utility function between labor and aggregate consumption (see Mankiw et al. (1986) and Fox (2002)):

$$U_j = \left( \mu C_j^{\frac{\rho-1}{\rho}} + (1-\mu)(1-L_j)^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}}$$

where  $C_j$  is the usual CES aggregator,  $\mu \in (0, 1)$  and  $\rho > 0$  is the elasticity of substitution between consumption and leisure.<sup>31</sup> The optimal choices are:

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<sup>30</sup>In the Appendix, we describe an algorithm that computes the equivalent variation numerically. In practice, we use the change in the domestic trade shares predicted by the non-CES model, to compute the gains in ACR and in our baseline model using Propositions 1 and 2. Moreover, since countries are symmetric the three models have the same change in domestic trade shares.

<sup>31</sup>It is worth noting that functional forms such as the ones used by Trabandt and Uhlig (2011) (Cobb Douglas) and King et al. (1988) (multiplicative) imply that income and substitution effects exactly offset each other. Therefore the optimal labor supply would be constant and the model would generate the same welfare gains as in ACR.

$$c_{ij}(\omega) = \frac{p_{ij}(\omega)^{-\sigma}}{P_j^{1-\sigma}} w_j L_j, \quad (36)$$

$$L_j = \left( 1 + \left( \frac{\mu}{1-\mu} \right)^{-\rho} \left( \frac{w_j}{P_j} \right)^{1-\rho} \right)^{-1}. \quad (37)$$

With this formulation the elasticity of labor supply is no longer constant as in the baseline model.

The trade equilibrium in the Armington setting is characterized by a vector of wages  $\{w_i\}$ , and labor choices  $\{L_i\}$  such that the system of equations (9) and (37) is solved. In the Melitz model instead the equilibrium is a vector of wages  $\{w_i\}$ , price indexes  $\{P_i\}$  and labor choices  $\{L_i\}$  such that the system of equations (9), (21) and (37) is solved.

We again consider two symmetric countries and numerically compute the gains from trade after a decrease in 10% of trade costs, for both the Armington and Melitz models, and compare them with ACR.<sup>32</sup> The simulations plotted in Figure 5 suggest that in the Armington model gains are still higher than ACR, as in the baseline model, and crucially depend on  $\rho$ , the elasticity of substitution between consumption and leisure. In particular, gains from trade are increasing in  $\rho$ : the more substitutable are  $C$  and leisure, the more the consumer is willing to give up some consumption to increase labor after a rise in the real wage, implying a stronger labor supply effect.<sup>33</sup> Obviously gains decrease in  $\mu$ , which is the weight the consumer puts in his utility on consumption relative to leisure. Similar forces are at play in the Melitz model, but the variety effect implies that gains are higher than ACR only when  $\rho$  is sufficiently high.

## 5 Concluding remarks

In this paper we bring labor supply to the forefront of the analysis regarding the relationship between trade and welfare. Overall, an important message emerges from our analysis: gains from trade significantly differ from what models with fixed labor supply predict, and depend crucially on the labor supply elasticity. In addition, we stress the important role of entry and variety effects in amplifying the impact of a change in trade costs through a simple real wage mechanism. Interesting avenues for future research emerge from our study.

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<sup>32</sup>As in the baseline model, the change in the domestic trade shares is the same in the two models because of symmetric countries.

<sup>33</sup>Note that when  $\rho \rightarrow \infty$  the utility becomes linear and labor hits the upper bound (normalized to 1 for simplicity), thus the increase in labor supply goes to zero and gains approach ACR.

From a theoretical standpoint, it would be instructive to extend our model to a setting with heterogeneous workers, to analyze the impact of trade policies on the skill premium in a framework different from what used so far in the literature. In addition, we hope that theory can serve as a guide for empirical analysis studying the relationship between trade policy shocks and labor supply.

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# Appendix A - Robustness

## An alternative utility function

We now consider the following utility specification:

$$U(C, L) = \frac{C_j^{1-\eta}}{1-\eta} + T_j^{1-\eta} \frac{(1-L_j)^{1-\gamma}}{1-\gamma}$$

where  $T_j$  is the level of total factor productivity (TFP), as in Mertens and Ravn (2011), and thus it is not affected by trade costs. This term  $T$ , that affects the disutility of work, is introduced to allow for a balanced growth path. The intuition for this rescaling is that when the TFP increases, the disutility of labor decreases and thus hours worked do not shrink to zero, consistent with the fact that TFP has increased in the last 30 years while aggregate hours stayed roughly constant. Also notice that this utility sets an upper bound to aggregate labor supply, thus it is useful to study whether our welfare results are affected by the functional form assumed. Since this utility is separable, the optimal consumption is the same as in baseline model, while the optimal labor choice is implicitly defined by the following equation:

$$\left(\frac{w_j}{TP_j}\right)^{\frac{\eta-1}{\gamma}} (L_j)^{\frac{\eta}{\gamma}} + L_j = 1 \quad (38)$$

The trade equilibrium is characterized by exactly the same equations as in the baseline model, except that equation (5) is replaced by equation (38). As in the baseline model, we consider two symmetric countries and perform numerical simulations for both the Armington and the Melitz models. We plot the gains from trade for this utility specification in Figure 6 assuming a 10% decrease in trade costs, and compare them with ACR.<sup>34</sup> We set  $\gamma \in [0, 2]$ , and as before  $\eta \in [0, 1.5]$  and the trade elasticity of 4. The graphs are very similar to the results of the baseline model: in the Armington model gains are always higher than ACR, while with free-entry the gains are higher than ACR only if  $\eta < 1$ .

## A Model with a non-tradeable sector

In this section we want to show that the predictions of our model are significantly different from a model with a non-tradeable sector. We keep the same assumptions of the baseline model, except that we assume inelastic labor supply and the existence of a non-tradeable

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<sup>34</sup>As in the baseline model, the change in the domestic trade shares is the same in the two models because of symmetric countries.

sector, similarly to Balistreri et al. (2010). We study both the Armington and the Melitz models. The consumer maximizes the following utility:

$$U_j = C_j^T + (C_j^{NT})^\alpha, \alpha \leq 1$$

where  $C_{NT}$  is a non-tradeable good, whose price is  $p_j^{NT}$ , and  $C_T$  is a Dixit-Stiglitz aggregator of differentiated traded goods. We choose this functional form since it aggregates consumption of tradeables and non-tradeable in the same way as the baseline utility does with consumption and labor.

The optimal solutions are:

$$c_{ij}^T = \frac{(p_{ij}^T)^{-\sigma}}{(P_j^T)^{1-\sigma}} y_j, \quad (39)$$

$$C_j^{NT} = \left( \frac{P_j^T \alpha}{p_j^{NT}} \right)^{\frac{1}{1-\alpha}} \quad (40)$$

where  $y_j \equiv w_j^{NT} L_j^{NT} + w_j^T L_j^T - p_j^{NT} C_j^{NT}$  is the income spent for the tradeable goods, and  $w_j^{NT} L_j^{NT}$  and  $w_j^T L_j^T$  are labor incomes from working in the non-tradeable and tradeable sectors, respectively.  $P_j^T$  is the Dixit-Stiglitz price index for the tradeable goods. Equation (40) has an intuitive explanation: it implies that the higher the price of the tradeable, the more the non-tradeable is consumed. We assume perfect mobility of labor across sectors, but immobility of labor across countries. This implies that  $w_j^T = w_j^{NT} = w_j$ . We assume a linear production function in labor for the non tradeable sector, with unitary productivity. This implies the following market clearing condition for the non-tradeable good is:

$$C_j^{NT} = L_j^{NT}. \quad (41)$$

We assume that the labor market clearing condition

$$L_j = L_j^T + L_j^{NT}, \quad (42)$$

and trade balance hold:

$$\sum_i \lambda_{ij} w_i L_i^T = w_i L_i^T, \quad (43)$$

where  $\lambda_{ij}$  are the trade shares.<sup>35</sup> It is easy to show that in the Armington model trade shares are simply:

$$\lambda_{ij} = \frac{(w_i \tau_{ij})^{1-\sigma}}{\sum_i (w_i \tau_{ij})^{1-\sigma}},$$

In the Melitz model instead trade shares are:

$$\lambda_{ij} = \frac{f_{ij}^{\frac{1-\sigma+\theta}{1-\sigma}} L_i^T (\tau_{ij} w_i)^{-\theta}}{\sum_k f_{kj}^{\frac{1-\sigma+\theta}{1-\sigma}} L_k^T (\tau_{kj} w_k)^{-\theta}}.$$

The trade equilibrium for the Armington model is characterized by a vector of wages  $\{w_i\}$  and labor allocations  $\{L_i^T, L_i^{NT}\}$  such that the system of equations (41), (42) and (43) is satisfied. Similarly, the trade equilibrium for the Melitz model is characterized by a vector of wages  $\{w_i\}$ , price indexes  $\{P_i\}$  and labor allocations  $\{L_i^T, L_i^{NT}\}$  such that the system of equations (21), (41), (43) and (42) is satisfied.

We now turn to the welfare analysis. We evaluate the welfare impact of a shock to trade costs using the equivalent variation defined by equation (13). We first start from the expenditure function:

$$e_j = P_j^T C_j^T + p_j^{NT} C_j^{NT}.$$

Using the constraint of the expenditure minimization problem  $C_j^T + (C_j^{NT})^\alpha \geq \bar{u}_j'$ , where  $\bar{u}_j'$  is the utility reached in the counterfactual equilibrium, we can write  $C_j^T$  as:

$$C_j^T = \bar{u}_j' - (C_j^{NT})^\alpha.$$

Substitute back  $C_j^T$  in the expenditure:

$$e(p_{ij}, \bar{u}_j') = P_j^T (\bar{u}_j' - (C_j^{NT})^\alpha) + p_j^{NT} C_j^{NT}, \quad (44)$$

which is interpreted as the level of expenditure, evaluated at initial prices, needed to reach the utility of the counterfactual equilibrium. We can use equation (13), the equation for trade shares and some algebra to write welfare gains in the Armington model as:

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<sup>35</sup>Trade balance implies that  $\sum_i X_{ij} + p_j^{NT} C_j^{NT} = w_j L_j$ , or equivalently  $\sum_i \lambda_{ij}^T (w_i L_i - p_i^{NT} C_i^{NT}) = w_j L_j - p_j^{NT} C_j^{NT}$ . Given that we assume unitary productivity in the non-tradeable sector and linearity in production, it holds that  $w_j = p_j^{NT}$ , so we have  $\sum_i \lambda_{ij}^T (w_i L_i - w_i L_i^{NT}) = w_j L_j - w_j L_j^{NT}$  and thus  $\sum_i \lambda_{ij}^T w_i L_i^T = w_i L_i^T$ .

$$\hat{W}_j = \left(\hat{\lambda}_{jj}\right)^{\zeta_A} \left[1 - \tilde{\alpha}_j \left(\lambda'_{jj}\right)^{\frac{\zeta_A}{\alpha-1}}\right] + \tilde{\alpha}_j \left(\lambda_{jj}\right)^{\frac{\zeta_A}{\alpha-1}} - 1, \quad (45)$$

where  $\tilde{\alpha}_j \equiv \left(\frac{\alpha^{\frac{1}{1-\alpha}} - \alpha^{\frac{\alpha}{1-\alpha}}}{L_j}\right)$ .<sup>36</sup> Similarly, in the Melitz model welfare gains can be written as:

$$\hat{W}_j = \left(\hat{\lambda}_{jj}\right)^{\zeta_M} \left[1 - \tilde{\alpha}_j \left(\vartheta_{jj}\lambda'_{jj}\right)^{\frac{\zeta_M}{\alpha-1}}\right] + \tilde{\alpha}_j \left(\vartheta_{jj}^{\zeta_M}\lambda_{jj}^{\zeta_M}\right)^{\frac{1}{\alpha-1}} - 1. \quad (46)$$

As before, we simulate two symmetric countries and assume a decrease in 10% of trade costs in the model with a non-tradeable sector. Then, we use the change in the domestic trade shares of the tradeable sector predicted by the model, to compute the gains in ACR and in our model using Propositions 1 and 2.<sup>37</sup> We run this exercise for different values for  $\alpha$ ,  $\varepsilon$  and  $\eta$ ; we set as before the trade elasticity to 4. We simulate both the Armington and Meltiz models. As Figure 7 shows, welfare gains are always *lower* than our model of elastic labor supply.<sup>38</sup> The reason is that in a model with a non-tradeable sector, the income given to the consumer can be used to purchase both tradeable and non-tradeable goods, while in our model the agent is compensated only with tradeable consumption and not with additional leisure. Moreover, in a model with a non-tradeable sector that uses linearly labor as factor of production, a trade liberalization simply induces a reallocation of labor toward the tradeable sector. In contrast, in our model if income effects are small then an increase in the real wage triggers an increase in the overall supply of labor, rising total income and shifting out the PPF of the economy.

## Appendix B - Proofs

### Proof of existence and uniqueness in the Armington model:

We can solve the system of equations of the model as finding the zeros of an excess

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<sup>36</sup>We simply have to substitute for  $u'$  in equation (44), and then for  $C^{NT}$  and  $C'$ . What we get is:

$$e(p_{ij}, u') = P \left( \frac{w'}{P'} L - \left( \frac{w'}{P'} \right)^{\frac{\alpha}{\alpha-1}} \alpha^{\frac{1}{1-\alpha}} + \left( \frac{w'}{P'} \right)^{\frac{\alpha}{\alpha-1}} \alpha^{\frac{\alpha}{1-\alpha}} - \alpha^{\frac{\alpha}{1-\alpha}} \left( \frac{w}{P} \right)^{\frac{\alpha}{\alpha-1}} \right) + w \alpha^{\frac{1}{1-\alpha}} \left( \frac{w}{P} \right)^{\frac{1}{\alpha-1}}$$

We then use the definition of equivalent variation in equation (13) to find welfare gains as function of the real wage. Finally, use the equation for trade shares to write the real wage as a function of domestic trade shares, and we get equation (45).

<sup>37</sup>Notice that the percentage change in the domestic trade shares of the tradeable sector is the same in the three models because of symmetric countries.

<sup>38</sup>They are higher than in our Melitz model only when  $\eta > 1$ , but such value for  $\eta$  is not consistent with the empirical evidence shown in Chetty (2012). See Section 3.

demand system  $Z(w_j)$ . We start from trade balance:

$$\sum_i \lambda_{ji}(w_i L_i) = w_j L_j,$$

and define the excess demand function:

$$Z(w_j) = \frac{1}{w_j} \left[ \sum_i \lambda_{ji}(w_i L_i) - w_j L_j \right] = 0.$$

Substitute the expressions for trade shares, labor and price index in the equation for  $Z(\mathbf{w})$ :

$$Z(\mathbf{w}) = \frac{1}{w_j} \left[ \sum_i (w_j \tau_{ji})^{1-\sigma} w_i^{\frac{1+\varepsilon}{1+\varepsilon\eta}} \left( \sum_j (w_j \tau_{ji})^{1-\sigma} \right)^{\frac{\varepsilon(1-\eta)+(1-\sigma)(1+\eta\varepsilon)}{(1+\eta\varepsilon)(\sigma-1)}} - w_j^{\frac{1+\varepsilon}{1+\varepsilon\eta}} \left( \sum_i (w_i \tau_{ij})^{1-\sigma} \right)^{\frac{\varepsilon(1-\eta)}{(1+\eta\varepsilon)(\sigma-1)}} \right]. \quad (47)$$

We verify that  $Z(\mathbf{w})$  has the following properties:

- $Z(\mathbf{w})$  is continuous.
- $Z(\mathbf{w})$  is homogenous of degree zero:

$$\begin{aligned} Z(\mathbf{wt}) &= \frac{1}{tw_j} \left[ \sum_i t^{1-\sigma} (w_j \tau_{ji})^{1-\sigma} t^{\frac{1+\varepsilon}{1+\varepsilon\eta}} w_i^{\frac{1+\varepsilon}{1+\varepsilon\eta}} t^{\frac{-\varepsilon(1-\eta)-(1-\sigma)(1+\eta\varepsilon)}{(1+\eta\varepsilon)}} \left( \sum_j (w_j \tau_{ji})^{1-\sigma} \right)^{\frac{\varepsilon(1-\eta)+(1-\sigma)(1+\eta\varepsilon)}{(1+\eta\varepsilon)(\sigma-1)}} \right] = \\ &= \frac{1}{tw_j} \left[ t \sum_i \frac{(w_j \tau_{ji})^{1-\sigma}}{\sum_j (w_j \tau_{ji})^{1-\sigma}} w_i^{\frac{1+\varepsilon}{1+\varepsilon\eta}} \left( \sum_j (w_j \tau_{ji})^{1-\sigma} \right)^{\frac{\varepsilon(1-\eta)+(1-\sigma)(1+\eta\varepsilon)}{(1+\eta\varepsilon)(\sigma-1)}} - tw_j^{\frac{1+\varepsilon}{1+\varepsilon\eta}} \left( \sum_i (w_i \tau_{ij})^{1-\sigma} \right)^{\frac{\varepsilon(1-\eta)}{(1+\eta\varepsilon)(\sigma-1)}} \right] = Z(\mathbf{w}). \end{aligned}$$

- $Z(\mathbf{w}) \cdot \mathbf{w} = 0$  (Walras' Law). Multiply equation (47) by  $w_j$ :

$$w_j Z(\mathbf{w}) = \left[ \sum_i \lambda_{ji}(w_i L_i) - w_j L_j \right],$$

and sum over  $j$ :



$$\begin{aligned}
& \sum_j \sum_i \lambda_{ji} w_i L_i - \sum_j w_j L_j = \\
& = \sum_j \sum_i X_{ji} - \sum_j w_j^2 L_j = \sum_j w_j L_j - \sum_j w_j L_j = 0.
\end{aligned}$$

- There exists a  $k > 0$  such that  $Z_j(\mathbf{w}) > -k$  for all  $j$ . Define  $k$  to be a lower bound for labor. This lower bound is bigger than zero, since labor is, from Equations (5) and (11):

$$L_j = (\lambda_{jj})^{\frac{\varepsilon(1-\eta)}{(1+\eta\varepsilon)(1-\sigma)}},$$

which is bigger than zero. Then we have:

$$\begin{aligned}
Z(w_j) &= \frac{1}{w_j} \left[ \sum_i \lambda_{ji} (w_i L_i) - w_j L_j \right] = \\
&= \frac{1}{w_j} \sum_i \lambda_{ji} (w_i L_i) - L_j \geq -L_j \geq -k.
\end{aligned}$$

- If there exists a sequence  $w^m \rightarrow w^0$ , where  $w^0 \neq 0$  and  $w_i^0 = 0$  for some  $i$ , then it must be that:

$$\max_j \{Z_j(w^m)\} \rightarrow \infty \quad (48)$$

Note that for any  $w \in \mathbf{R}_{++}^n$ , we have:

$$\begin{aligned}
\max_k Z_k(w) &= \max_k \frac{1}{w_k} \left[ \sum_i \lambda_{ki} (w_i L_i) - w_k L_k \right] = \\
&\geq \max_{k,i} \frac{1}{w_k} \lambda_{ki} (w_i L_i) - \max_k L_k.
\end{aligned}$$

The above equation implies that  $\max_j \{Z_j(w^m)\} \rightarrow \infty$  holds only if, for the wage sequence  $\{w^m\}$ , it holds that:

$$\begin{aligned}
& \max_{k,i} \frac{w_i^m}{w_k^m} \lambda_{ki} (w^m) L_i = \\
& \max_{k,i} \frac{(w_i^m)^{\frac{1+\varepsilon}{1+\eta\varepsilon}}}{w_k^m} \lambda_{ki} (w^m) \left( \sum_j (w_j^m \tau_{ji})^{1-\sigma} \right)^{\frac{\varepsilon(\eta-1)}{1+\eta\varepsilon}} \rightarrow \infty \quad (49)
\end{aligned}$$

Note that:

$$\lambda_{ki}(w^m) \geq \frac{(w_k^m)^{1-\sigma}}{\sum_k (w_k^m)^{1-\sigma}}$$

Therefore we can write Equation (49) as:

$$\begin{aligned} & \max_{k,i} \frac{(w_i^m)^{\frac{1+\varepsilon}{1+\eta\varepsilon}}}{w_k^m} \lambda_{ki}(w^m) \left( \sum_i (w_i^m \tau_{ij})^{1-\sigma} \right)^{\frac{\varepsilon(\eta-1)}{1+\eta\varepsilon}} \\ & \geq \frac{(w_i^m)^{\frac{1+\varepsilon}{1+\eta\varepsilon}}}{(w_k^m)^\sigma} \frac{(\sum_i (w_i^m)^{1-\sigma})^{\frac{\varepsilon(\eta-1)}{1+\eta\varepsilon}}}{\sum_k (w_k^m)^{1-\sigma}} \geq \frac{(w_i^m)^{\frac{(1-\sigma)\varepsilon(\eta-1)+1+\varepsilon}{1+\eta\varepsilon}}}{(w_k^m)^\sigma \sum_k (w_k^m)^{1-\sigma}} \\ & \geq \frac{\max_i (w_i^m)^\zeta}{\min_k (w_k^m)^\sigma \sum_k \min_k (w_k^m)^{1-\sigma}} \end{aligned}$$

if  $\sigma > 1$  for any  $i$  and  $k$ , where  $\zeta \equiv \frac{(1-\sigma)\varepsilon(\eta-1)+(1+\varepsilon)}{1+\eta\varepsilon}$ . Then:

$$\max_{k,i} \frac{w_i^m}{w_k^m} \lambda_{ki}(w^m) L_i \geq \frac{\max_i (w_i^m)^\zeta}{\min_k (w_k^m)} \frac{1}{\sum_k},$$

where  $\sum_k$  is a constant (i.e. since you can pull out the min). Now since  $\max_i (w_i^m)^\zeta \rightarrow \max_i (w_i^0)^\zeta > 0$ , and  $\min_k w_k^m \rightarrow \min_k w_k^0 = 0$ , we have that:

$$\frac{\max_i (w_i^m)^\zeta}{\min_k (w_k^m)} \rightarrow \infty.$$

Therefore  $\max_{k,i} \frac{w_i^m}{w_k^m} \lambda_{ki}(w^m) L_i \rightarrow \infty$ , and thus condition (48) is verified.

- Gross substitutes property: we want to verify that  $\frac{\partial Z(w_j)}{\partial w_k} > 0$  holds:

$$\begin{aligned} \frac{\partial Z(w_j)}{\partial w_k} &= w_j^{-\sigma} (\tau_{ki})^{1-\sigma} \left[ \frac{1+\varepsilon}{1+\varepsilon\eta} w_k^{\frac{\varepsilon(1-\eta)}{1+\varepsilon\eta}} \left( \sum_j (w_j \tau_{ji})^{1-\sigma} \right)^{\frac{\varepsilon(1-\eta)+(1-\sigma)(1+\eta\varepsilon)}{(1+\eta\varepsilon)(\sigma-1)}} \right] \\ & - w_j^{-\sigma} (\tau_{ki})^{1-\sigma} \left[ w_k^{\frac{1+\varepsilon}{1+\varepsilon\eta}} \frac{\varepsilon(1-\eta) + (1-\sigma)(1+\eta\varepsilon)}{(1+\eta\varepsilon)(\sigma-1)} (\sigma-1) w_k^{-\sigma} \tau_{ki}^{1-\sigma} \left( \sum_j (w_j \tau_{ji})^{1-\sigma} \right)^{\frac{\varepsilon(1-\eta)+2(1-\sigma)(1+\eta\varepsilon)}{(1+\eta\varepsilon)(\sigma-1)}} \right] \end{aligned}$$

$$+(\sigma - 1)w_k^{-\sigma}\tau_{ki}^{1-\sigma}w_j^{\frac{\varepsilon(1-\eta)}{1+\varepsilon\eta}}\left(\sum_i(w_i\tau_{ij})^{1-\sigma}\right)^{\frac{\varepsilon(1-\eta)}{(1+\varepsilon)(\sigma-1)}-1}$$

A sufficient but not necessary condition for this to be positive is that  $\varepsilon(1 - \eta) + (1 - \sigma)(1 + \eta\varepsilon) < 0$ , or  $\sigma > 1 + \frac{\varepsilon(1-\eta)}{1+\eta\varepsilon}$  holds. By invoking Propositions 17.B.2, 17.C.1 and 17.F.3 of Mas-Colell et al. (1995), equilibrium existence and uniqueness are proved. ■

**Proof of Proposition 1:** From the expenditure minimization problem the optimal choice for consumption is:

$$c_{ij} = \left(\frac{p_{ij}}{P_j}\right)^{-\sigma} C_j,$$

so the minimum expenditure is:

$$e_j(p_{ij}) = \sum_i p_{ij}c_{ij} = P_j C_j.$$

From the constraint  $\frac{C_j^{1-\eta}}{1-\eta} - \frac{L_j^{1+1/\varepsilon}}{1+1/\varepsilon} \geq \bar{u}'_j$  we have that:

$$C(\bar{u}') = \left[ (1 - \eta) \left( \bar{u}'_j + \frac{L_j^{1+1/\varepsilon}}{1 + 1/\varepsilon} \right) \right]^{\frac{1}{1-\eta}},$$

so the expenditure becomes:

$$e_j(p_{ij}, \bar{u}'_j) = \left[ (1 - \eta) \left( \bar{u}'_j + \frac{L_j^{1+1/\varepsilon}}{1 + 1/\varepsilon} \right) \right]^{\frac{1}{1-\eta}} P_j.$$

Welfare gains are:

$$\hat{W} = \frac{e_j(p_{ij}, \bar{u}'_j) - e_j(p_{ij}, \bar{u}_j)}{e_j(p_{ij}, \bar{u}_j)} = \frac{e_j(p_{ij}, \bar{u}'_j) - w_j L_j}{w_j L_j} = \frac{\left[ (1 - \eta) \left( \bar{u}'_j + \frac{L_j^{1+1/\varepsilon}}{1+1/\varepsilon} \right) \right]^{\frac{1}{1-\eta}} P_j}{w_j L_j} - 1.$$

Note that in the inelastic labor case we have that:

$$\hat{W} = \frac{u'_j P_j}{w_j L_j} - 1 = \frac{w'_j L'_j P_j}{P'_j w_j L_j} - 1 = -d \ln P_j,$$

since the wage is the numeraire and labor supply is fixed. Instead in our model, substituting

for  $u'_j$ :

$$\begin{aligned}
\hat{W} &= (1-\eta)^{\frac{1}{1-\eta}} \frac{\left( \frac{1}{1-\eta} \left( \frac{w' L'}{P'} \right)^{1-\eta} - \frac{L'^{1+1/\varepsilon}}{1+1/\varepsilon} + \frac{L^{1+1/\varepsilon}}{1+1/\varepsilon} \right)^{\frac{1}{1-\eta}} P_j}{w_j L_j} - 1 = \\
&= (1-\eta)^{\frac{1}{1-\eta}} \frac{\left( \frac{1}{1-\eta} \left( \frac{w'_j}{P'_j} \right)^{\frac{(1+\varepsilon)(1-\eta)}{1+\eta\varepsilon}} - \frac{\varepsilon}{1+\varepsilon} \left( \frac{w'_j}{P'_j} \right)^{\frac{(1+\varepsilon)(1-\eta)}{1+\eta\varepsilon}} + \frac{\varepsilon}{1+\varepsilon} \left( \frac{w_j}{P_j} \right)^{\frac{(1+\varepsilon)(1-\eta)}{1+\eta\varepsilon}} \right)^{\frac{1}{1-\eta}} P_j}{w_j L_j} - 1 = \\
&= (1-\eta)^{\frac{1}{1-\eta}} (\lambda_{jj})^{-\frac{(1+\varepsilon)}{(1+\eta\varepsilon)(1-\sigma)}} \left( \left( \frac{1}{1-\eta} - \frac{\varepsilon}{1+\varepsilon} \right) (\lambda'_{jj})^{\frac{(1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)(1-\sigma)}} + \frac{\varepsilon}{1+\varepsilon} (\lambda_{jj})^{\frac{(1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)(1-\sigma)}} \right)^{\frac{1}{1-\eta}} - 1 \\
&= (1-\eta)^{\frac{1}{1-\eta}} (\hat{\lambda}_{jj})^\varphi \left( \frac{1}{1-\eta} + \frac{\varepsilon}{1+\varepsilon} \left( (\hat{\lambda}_{jj})^{-\varphi(1-\eta)} - 1 \right) \right)^{\frac{1}{1-\eta}} - 1,
\end{aligned}$$

where  $\varphi \equiv \frac{(1+\varepsilon)}{(1+\eta\varepsilon)(1-\sigma)} < 0$ . We now want to show that gains are always higher than in ACR:

$$(1-\eta)^{\frac{1}{1-\eta}} (\hat{\lambda}_{jj})^\varphi \left( \frac{1}{1-\eta} + \frac{\varepsilon}{1+\varepsilon} \left( (\hat{\lambda}_{jj})^{-\varphi(1-\eta)} - 1 \right) \right)^{\frac{1}{1-\eta}} > (\hat{\lambda}_{jj})^{\frac{1}{1-\sigma}}$$

Consider first the case of  $\eta < 1$ . Rearrange the inequality:

$$(1-\eta) (\hat{\lambda}_{jj})^{\frac{(1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)(1-\sigma)}} \left( \frac{1}{1-\eta} + \frac{\varepsilon}{1+\varepsilon} \left( (\hat{\lambda}_{jj})^{-\frac{(1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)(1-\sigma)}} - 1 \right) \right) > (\hat{\lambda}_{jj})^{\frac{1-\eta}{1-\sigma}} \implies$$

$$(1-\eta) (\hat{\lambda}_{jj})^{\frac{\varepsilon(1-\eta)^2}{(1+\eta\varepsilon)(1-\sigma)}} \left( \frac{1}{1-\eta} + \frac{\varepsilon}{1+\varepsilon} \left( (\hat{\lambda}_{jj})^{-\frac{(1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)(1-\sigma)}} - 1 \right) \right) > 1 \implies$$

$$\left( \hat{\lambda}_{jj} \right)^{\frac{\varepsilon(1-\eta)^2}{(1+\eta\varepsilon)(1-\sigma)}} + \left( \hat{\lambda}_{jj} \right)^{\frac{\varepsilon(1-\eta)^2 - (1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)(1-\sigma)}} \frac{(1-\eta)\varepsilon}{1+\varepsilon} > 1 + \left( \hat{\lambda}_{jj} \right)^{\frac{\varepsilon(1-\eta)^2}{(1+\eta\varepsilon)(1-\sigma)}} \frac{(1-\eta)\varepsilon}{1+\varepsilon} \implies$$

$$\left( \hat{\lambda}_{jj} \right)^\rho + \left( \hat{\lambda}_{jj} \right)^{\rho - \frac{(1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)(1-\sigma)}} \frac{(1-\eta)\varepsilon}{1+\varepsilon} > 1 + \left( \hat{\lambda}_{jj} \right)^\rho \frac{(1-\eta)\varepsilon}{1+\varepsilon},$$

where  $\rho \equiv \frac{\varepsilon(1-\eta)^2}{(1+\eta\varepsilon)(1-\sigma)} < 0$ . Since  $\hat{\lambda}_{jj} < 1$  after a trade liberalization, note that  $\left(\hat{\lambda}_{jj}\right)^{\rho - \frac{(1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)(1-\sigma)}} > \left(\hat{\lambda}_{jj}\right)^\rho > 1$ . Rearrange:

$$\left(\hat{\lambda}_{jj}\right)^{\rho - \frac{(1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)(1-\sigma)}} \frac{(1-\eta)\varepsilon}{1+\varepsilon} + \left(\hat{\lambda}_{jj}\right)^\rho \frac{1+\eta\varepsilon}{1+\varepsilon} > 1,$$

which always holds if  $\varepsilon > 0$  and  $\eta < 1$ . Indeed note that when  $\varepsilon = 0$ , that is the inelastic labor case, we have that  $\rho = 0$  and the LHS is equal to 1. It is then easy to see that the LHS is increasing in  $\varepsilon$ , so the inequality always holds for  $\varepsilon > 0$ .

Consider now the case of  $\eta > 1$ . Gains are higher than ACR if and only if:

$$(1-\eta)^{\frac{1}{1-\eta}} \left(\hat{\lambda}_{jj}\right)^\varphi \left(\frac{1}{1-\eta} + \frac{\varepsilon}{1+\varepsilon} \left(\left(\hat{\lambda}_{jj}\right)^{-\varphi(1-\eta)} - 1\right)\right)^{\frac{1}{1-\eta}} > \left(\hat{\lambda}_{jj}\right)^{\frac{1}{1-\sigma}} \implies$$

$$(1-\eta) \left(\hat{\lambda}_{jj}\right)^{\frac{(1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)(1-\sigma)}} \left(\frac{1}{1-\eta} + \frac{\varepsilon}{1+\varepsilon} \left(\left(\hat{\lambda}_{jj}\right)^{-\frac{(1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)(1-\sigma)}} - 1\right)\right) < \left(\hat{\lambda}_{jj}\right)^{\frac{1-\eta}{1-\sigma}},$$

where the inequality is reversed since we are raising both sides to a negative number. Then following the same steps as before we have:

$$\left(\hat{\lambda}_{jj}\right)^\rho + \left(\hat{\lambda}_{jj}\right)^{\rho - \frac{(1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)(1-\sigma)}} \frac{(1-\eta)\varepsilon}{1+\varepsilon} < 1 + \left(\hat{\lambda}_{jj}\right)^\rho \frac{(1-\eta)\varepsilon}{1+\varepsilon} \implies$$

$$\left(\hat{\lambda}_{jj}\right)^{\rho - \frac{(1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)(1-\sigma)}} (1-\eta)\varepsilon < 1 + \varepsilon - (1+\eta\varepsilon) \left(\hat{\lambda}_{jj}\right)^\rho.$$

It is easy to see that the RHS is always positive, while the LHS is always negative since  $\eta > 1$ , so the inequality holds and gains are higher than ACR. ■

### Derivations of equilibrium equations for the Melitz model

Throughout the Appendix we assume that the usual condition  $\theta > \sigma - 1$  holds. Note that the price index is:

$$P_j^{1-\sigma} = \sum_i J_i \int_{z_{ij}^*}^{\infty} \left(\frac{\sigma}{\sigma-1} \tau_{ij} w_i\right)^{1-\sigma} \theta z^{\sigma-\theta-2} dz =$$

$$= \sum_i J_i \gamma (\tau_{ij} w_i)^{1-\sigma} (z_{ij}^*)^{-\theta-1+\sigma},$$

where  $\gamma \equiv \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} \frac{\theta}{\theta-\sigma+1}$ . The zero-profit condition

$$\sum_j \int_{z_{ij}^*}^{\infty} \left(\frac{\sigma}{\sigma-1} \tau_{ij} w_i\right)^{1-\sigma} \frac{w_j L_j}{\sigma P_j^{1-\sigma}} \theta z^{\sigma-\theta-2} dz - \sum_j \int_{z_{ij}^*}^{\infty} w_j f_{ij} \theta z^{-\theta-1} dz = w_i f_e,$$

can be simplified as:

$$\frac{\sigma-1}{\theta-\sigma+1} \sum_j w_j f_{ij} (z_{ij}^*)^{-\theta} = w_i f_e. \quad (50)$$

The labor market condition is:

$$\begin{aligned} J_i \sum_j \int_{z_{ij}^*}^{\infty} \tau_{ij} \left(\frac{\sigma}{\sigma-1} \tau_{ij} w_i\right)^{-\sigma} \frac{w_j L_j}{P_j^{1-\sigma}} \theta z^{\sigma-\theta-2} dz + J_i f_e + \sum_j J_j \int_{z_{ji}^*}^{\infty} f_{ji} \theta z^{-\theta-1} dz &= L_i \implies \\ J_i \sum_j \tau_{ij} \left(\frac{\sigma}{\sigma-1} \tau_{ij} w_i\right)^{-\sigma} \frac{w_j L_j}{P_j^{1-\sigma}} \theta \frac{(z_{ij}^*)^{\sigma-\theta-1}}{-\sigma+\theta+1} + J_i f_e + \sum_j J_j f_{ji} (z_{ji}^*)^{-\theta} &= L_i \implies \\ J_i \sum_j \tau_{ij} \frac{\theta}{\theta-\sigma+1} \frac{f_{ij} w_j \sigma}{\left(\frac{\sigma}{\sigma-1} \tau_{ij} w_i\right)} (z_{ij}^*)^{-\theta} + J_i f_e + \sum_j J_j f_{ji} (z_{ji}^*)^{-\theta} &= L_i \implies \\ J_i \frac{\theta(\sigma-1)}{\theta-\sigma+1} \sum_j \frac{w_j f_{ij}}{w_i} (z_{ij}^*)^{-\theta} + J_i f_e + \sum_j J_j f_{ji} (z_{ji}^*)^{-\theta} &= L_i. \end{aligned} \quad (51)$$

Plug Equation (50) into Equation (51):

$$J_i f_e \theta + J_i f_e + \sum_j J_j f_{ji} (z_{ij}^*)^{-\theta} = L_i.$$

From the price index equation, we have:

$$P_j^{1-\sigma} = \sum_i J_i \frac{\theta}{\theta-\sigma+1} (z_{ij}^*)^{-\theta} \frac{f_{ij} \sigma (P_j)^{1-\sigma}}{L_j},$$

which implies that:

$$L_j = \frac{\theta\sigma}{\theta - \sigma + 1} \sum_i J_i (z_{ij}^*)^{-\theta} f_{ij}.$$

Therefore we can write the free-entry as:

$$J_i f_e \theta + J_i f_e + L_i \frac{\theta - \sigma + 1}{\theta\sigma} = L_i,$$

and get the equation for entrants:

$$J_i = \frac{\sigma - 1}{\sigma\theta f_e} L_i = \frac{\sigma - 1}{\sigma\theta f_e} \left( \frac{w_i}{P_i} \right)^{\frac{\varepsilon(1-\eta)}{1+\eta\varepsilon}}.$$

Trade shares are:

$$\lambda_{ij} = \frac{J_i \int_{z_{ij}^*}^{\infty} p_{ij}(z) c_{ij}(z) g_i(z) dz}{w_j L_j} = \frac{J_i \int_{z_{ij}^*}^{\infty} p_{ij}(z)^{1-\sigma} g_i(z) dz}{P_j^{1-\sigma}}.$$

Substituting for the price index, for  $J$  and for labor, we get Equation (25) in the main text.

To find the expression for real wage we can rewrite trade shares as:

$$\frac{J_i \gamma (\tau_{ij} w_i)^{1-\sigma} (z_{ij}^*)^{\sigma-\theta-1}}{\lambda_{ij}} = P_j^{1-\sigma}.$$

Substitute for the cutoff, for  $J$  and for labor to get the real wage as a function of domestic trade shares:

$$\begin{aligned} \frac{\gamma (w_j)^{1-\sigma}}{\lambda_{jj}} \frac{\sigma - 1}{\sigma\theta f_e} \left( \frac{w_j}{P_j} \right)^{\frac{\varepsilon(1-\eta)}{1+\eta\varepsilon}} \left( \frac{f_{ij} \sigma P_j^{\frac{(1-\sigma)(1+\eta\varepsilon)+\varepsilon(1-\eta)}{1+\eta\varepsilon}}}{\left( \frac{\sigma}{\sigma-1} \tau_{ij} w_i \right)^{1-\sigma} (w_j)^{\frac{\varepsilon(1-\eta)}{1+\eta\varepsilon}}} \right)^{\frac{\sigma-1-\theta}{\sigma-1}} &= P_j^{1-\sigma} \implies \\ \gamma f_{jj}^{\frac{\sigma-1-\theta}{\sigma-1}} \left( \frac{\sigma}{\sigma-1} \right)^{\sigma-1-\theta} \sigma^{\frac{\sigma-1-\theta}{\sigma-1}} \frac{\sigma-1}{\sigma\theta f_e} \left( \frac{w_j}{P_j} \right)^{\frac{\varepsilon(1-\eta)+(1-\sigma)(1+\eta\varepsilon)}{1+\eta\varepsilon}} \left( \frac{P_j^{\frac{(1-\sigma)(1+\eta\varepsilon)+\varepsilon(1-\eta)}{1+\eta\varepsilon}}}{(w_j)^{\frac{\varepsilon(1-\eta)+(1-\sigma)(1+\eta\varepsilon)}{1+\eta\varepsilon}}} \right)^{\frac{\sigma-1-\theta}{\sigma-1}} &= \lambda_{jj} \implies \\ \left( \frac{w_j}{P_j} \right) &= \left[ \frac{\lambda_{jj}}{\gamma f_{jj}^{\frac{\sigma-1-\theta}{\sigma-1}} \left( \frac{\sigma}{\sigma-1} \right)^{\sigma-1-\theta} \sigma^{\frac{\sigma-1-\theta}{\sigma-1}} \frac{\sigma-1}{\sigma\theta f_e}} \right]^{\frac{(1+\eta\varepsilon)(1-\sigma)}{\theta\varepsilon(1-\eta)+\theta(1-\sigma)(1+\eta\varepsilon)}} = \vartheta^\zeta \lambda_{jj}^\zeta. \end{aligned}$$

**Proof of Proposition 2:** Recall that in the Melitz model the real wage is:

$$\frac{w_j}{P_j} = \vartheta^\zeta \lambda_{jj}^\zeta,$$

where  $\zeta \equiv \frac{(1+\eta\varepsilon)(\sigma-1)}{\theta(1+\varepsilon-\sigma(1+\eta\varepsilon))} < 0$ . Thus welfare gains are, from proposition 1:

$$\begin{aligned} \hat{W} &= (1-\eta)^{\frac{1}{1-\eta}} \frac{\left(\frac{1}{1-\eta} \left(\frac{w'L'}{P'}\right)^{1-\eta} - \frac{L'^{1+1/\varepsilon}}{1+1/\varepsilon} + \frac{L^{1+1/\varepsilon}}{1+1/\varepsilon}\right)^{\frac{1}{1-\eta}} P_j}{w_j L_j} - 1 = \\ &= (1-\eta)^{\frac{1}{1-\eta}} \left(\hat{\lambda}_{jj}\right)^\varphi \left(\frac{1}{1-\eta} + \frac{\varepsilon}{1+\varepsilon} \left(\left(\hat{\lambda}_{jj}\right)^{-\varphi(1-\eta)} - 1\right)\right)^{\frac{1}{1-\eta}} - 1, \end{aligned}$$

where  $\varphi \equiv \frac{\zeta(1+\varepsilon)}{(1+\eta\varepsilon)}$ . We now want to show that gains are always higher than in ACR:

$$(1-\eta)^{\frac{1}{1-\eta}} \left(\hat{\lambda}_{jj}\right)^\varphi \left(\frac{1}{1-\eta} + \frac{\varepsilon}{1+\varepsilon} \left(\left(\hat{\lambda}_{jj}\right)^{-\varphi(1-\eta)} - 1\right)\right)^{\frac{1}{1-\eta}} > \left(\hat{\lambda}_{jj}\right)^{-\frac{1}{\theta}}.$$

Consider first the case of  $\eta < 1$ . Rearrange the inequality:

$$(1-\eta) \left(\hat{\lambda}_{jj}\right)^{\frac{\zeta(1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)}} \left(\frac{1}{1-\eta} + \frac{\varepsilon}{1+\varepsilon} \left(\left(\hat{\lambda}_{jj}\right)^{-\frac{\zeta(1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)}} - 1\right)\right) > \left(\hat{\lambda}_{jj}\right)^{-\frac{1-\eta}{\theta}} \implies$$

$$(1-\eta) \left(\hat{\lambda}_{jj}\right)^{\frac{(\sigma-1)(1+\varepsilon)(1-\eta) + (1+\varepsilon-\sigma(1+\eta\varepsilon))(1-\eta)}{\theta(1+\varepsilon-\sigma(1+\eta\varepsilon))}} \left(\frac{1}{1-\eta} + \frac{\varepsilon}{1+\varepsilon} \left(\left(\hat{\lambda}_{jj}\right)^{-\frac{(1+\varepsilon)(1-\eta)(\sigma-1)}{\theta(1+\varepsilon-\sigma(1+\eta\varepsilon))}} - 1\right)\right) > 1 \implies$$

$$\left(\hat{\lambda}_{jj}\right)^{\rho + \frac{(1-\eta)}{\theta}} + \frac{\varepsilon(1-\eta)}{1+\varepsilon} \left(\left(\hat{\lambda}_{jj}\right)^{\frac{(1-\eta)}{\theta}} - \left(\hat{\lambda}_{jj}\right)^{\rho + \frac{(1-\eta)}{\theta}}\right) > 1,$$

where  $\rho \equiv \frac{(\sigma-1)(1+\varepsilon)(1-\eta)}{\theta(1+\varepsilon-\sigma(1+\eta\varepsilon))} < 0$  since  $\sigma > \frac{1+\varepsilon}{1+\eta\varepsilon}$  from Equation (12). Then:

$$\left(\hat{\lambda}_{jj}\right)^{\rho + \frac{(1-\eta)}{\theta}} + \frac{\varepsilon(1-\eta)}{1+\varepsilon} \left(\hat{\lambda}_{jj}\right)^{\frac{(1-\eta)}{\theta}} > 1 + \frac{\varepsilon(1-\eta)}{1+\varepsilon} \left(\hat{\lambda}_{jj}\right)^{\rho + \frac{(1-\eta)}{\theta}} \implies$$

$$\left(\hat{\lambda}_{jj}\right)^{\frac{(1-\eta)}{\theta}} \frac{\varepsilon(1-\eta)}{1+\varepsilon} + \left(\hat{\lambda}_{jj}\right)^{\rho + \frac{(1-\eta)}{\theta}} \frac{1+\eta\varepsilon}{1+\varepsilon} > 1,$$

which always holds if  $\varepsilon > 0$  and  $\eta < 1$ . Indeed note that when  $\varepsilon = 0$ , that is the inelastic labor case, we have that  $\rho + \frac{(1-\eta)}{\theta} = 0$  and the LHS is equal to 1. It is then easy to see that



the LHS is increasing in  $\varepsilon$ , so the inequality always holds for  $\varepsilon > 0$ . Consider now the case of  $\eta > 1$ . Gains are higher than ACR if and only if:

$$(1 - \eta)^{\frac{1}{1-\eta}} (\hat{\lambda}_{jj})^\varphi \left( \frac{1}{1-\eta} + \frac{\varepsilon}{1+\varepsilon} \left( (\hat{\lambda}_{jj})^{-\varphi(1-\eta)} - 1 \right) \right)^{\frac{1}{1-\eta}} > (\hat{\lambda}_{jj})^{-\frac{1}{\theta}} \implies$$

$$(1 - \eta) (\hat{\lambda}_{jj})^{\frac{\zeta(1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)}} \left( \frac{1}{1-\eta} + \frac{\varepsilon}{1+\varepsilon} \left( (\hat{\lambda}_{jj})^{-\frac{\zeta(1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)}} - 1 \right) \right) < (\hat{\lambda}_{jj})^{-\frac{1-\eta}{\theta}},$$

where the inequality is reversed since we are raising both sides for a negative number. Then following the same steps as before we have:

$$(\hat{\lambda}_{jj})^{\frac{(1-\eta)}{\theta}} \frac{\varepsilon(1-\eta)}{1+\varepsilon} + (\hat{\lambda}_{jj})^{\rho + \frac{(1-\eta)}{\theta}} \frac{1+\eta\varepsilon}{1+\varepsilon} < 1.$$

Note that now  $\rho > 0$  since  $\eta > 1$ , so  $(\hat{\lambda}_{jj})^{\rho + \frac{(1-\eta)}{\theta}} < 1$  and  $(\hat{\lambda}_{jj})^{\frac{(1-\eta)}{\theta}} > 1$ . It is then easy to see that, as long as condition (12) is satisfied, the LHS is bigger than one, so the inequality does not hold and gains are lower than ACR. ■

**Multiple sectors model - Armington.** We consider an extension of the model with multiple sectors, as in Costinot et al. (2010), Caliendo and Parro (2010) and Ossa (2012). We assume that the representative agent has a two-tier aggregator of consumption, with the upper-tier being a Cobb-Douglas function of consumption from the various sectors, and the lower-tier being a Dixit-Stiglitz function with elasticity of substitution  $\sigma > 1$ . Therefore the utility is:

$$U_j = \frac{C_j^{1-\eta}}{1-\eta} - \frac{L_j^{1+1/\varepsilon}}{1+1/\varepsilon},$$

where total consumption  $C_j$  is:

$$C_j = \Pi_{s=1}^S (C_j^s)^{\gamma_j^s},$$

with consumption shares  $0 < \gamma_j^s \leq 1$  such that  $\sum_{s=1}^S \gamma_j^s = 1$ , and each  $C_j^s$  being:

$$C_j^s = \left( \sum_i (c_{ij}^s)^{\frac{\sigma^s-1}{\sigma^s}} \right)^{\frac{\sigma^s}{\sigma^s-1}}.$$

Note that the elasticity of substitution differs across sectors. It is easy to show that the optimal choices are:

$$c_{ij}^s = \frac{(p_{ij}^s)^{-\sigma^s}}{(P_j^s)^{1-\sigma^s}} \gamma_j^s w_j L_j,$$

$$L_j = \left( \frac{w_j}{P_j} \right)^{\frac{\varepsilon(1-\eta)}{1+\eta\varepsilon}},$$

and the price index in country  $j$  is:

$$P_j = \frac{\prod_{s=1}^S (P_j^s)^{\gamma_j^s}}{\tilde{\gamma}_j},$$

where  $\tilde{\gamma}_j \equiv \prod_{s=1}^S (\gamma_j^s)^{\gamma_j^s}$  and  $P_{s,j}$  is the sectoral price index:

$$P_{s,j} = \left( \sum_i (p_{ij}^s)^{1-\sigma^s} \right)^{\frac{1}{1-\sigma^s}}.$$

We assume perfect mobility of labor within a country, so the wage is equalized across sectors. In the simple framework of the Armington model, sectoral trade shares are:

$$\lambda_{ij}^s = \frac{(w_i \tau_{ij}^s)^{1-\sigma^s}}{\sum_k (w_k \tau_{kj}^s)^{1-\sigma^s}}, \quad (52)$$

implying that the real wage is:

$$\frac{w_j}{P_j} = \prod_{s=1}^S (\lambda_{jj}^s)^{\frac{\gamma_j^s}{1-\sigma^s}}. \quad (53)$$

As in the baseline model, welfare gains are computed using the equivalent variation. The expenditure minimization problem leads to:

$$c_{ij}^s = \frac{(p_{ij}^s)^{-\sigma}}{(P_j^s)^{-\sigma}} C_j^s$$

thus the minimum expenditure is:

$$\begin{aligned}
e_j(p_{ij}, \bar{u}_j') &= \sum_s \sum_i P_{ij}^s C_{ij}^s = \sum_s \sum_i \frac{(p_{ij}^s)^{1-\sigma}}{(P_j^s)^{-\sigma}} C_j^s = \\
&= \sum_s P_j^s \frac{\gamma_j^s w_j L_j}{P_j^s} = w_j L_j
\end{aligned}$$

since  $\sum_{s=1}^S \gamma_j^s = 1$ . Note that  $C$  is no longer equal to  $wL/P$ , since:

$$\begin{aligned}
CP &= \prod_{s=1}^S (C_{s,j})^{\gamma_j^s} \prod_{s=1}^S (P_{s,j})^{\gamma_j^s} = \prod_{s=1}^S (P_{s,j} C_{s,j})^{\gamma_j^s} \\
&= \prod_{s=1}^S \left( P_{s,j} \frac{\gamma_j^s w_j L_j}{P_{s,j}} \right)^{\gamma_j^s} = (w_j L_j)^{\sum_s \gamma_j^s} \prod_{s=1}^S (\gamma_j^s)^{\gamma_j^s} = \tilde{\gamma} w_j L_j,
\end{aligned}$$

where  $\tilde{\gamma}_j \equiv \prod_{s=1}^S (\gamma_j^s)^{\gamma_j^s}$ . So we have:

$$e_j(p_{ij}, \bar{u}_j') = w_j L_j = \frac{C_j P_j}{\tilde{\gamma}_j}.$$

From the constraint  $\frac{C_j^{1-\eta}}{1-\eta} - \frac{L_j^{1+1/\varepsilon}}{1+1/\varepsilon} \geq \bar{u}_j$  we have that:

$$C = \left[ (1-\eta) \left( \bar{u}_j' + \frac{L_j^{1+1/\varepsilon}}{1+1/\varepsilon} \right) \right]^{\frac{1}{1-\eta}}.$$

So the expenditure becomes:

$$e_j(p_{ij}, \bar{u}_j') = \left[ (1-\eta) \left( \bar{u}_j' + \frac{L_j^{1+1/\varepsilon}}{1+1/\varepsilon} \right) \right]^{\frac{1}{1-\eta}} \frac{P_j}{\tilde{\gamma}_j}.$$

Welfare gains are:

$$\begin{aligned}
\hat{W}_j &= \frac{e_j(p_{ij}, \bar{u}_j') - e(p_{ij}, \bar{u}_j)}{e(p_{ij}, \bar{u}_j)} = \frac{e_j(p_{ij}, \bar{u}_j') - w_j L_j}{w_j L_j} = \frac{\left[ (1-\eta) \left( \bar{u}_j' + \frac{L_j^{1+1/\varepsilon}}{1+1/\varepsilon} \right) \right]^{\frac{1}{1-\eta}} P_j}{w_j L_j \tilde{\gamma}_j} - 1 = \\
&= (1-\eta)^{\frac{1}{1-\eta}} \frac{\left( \frac{1}{1-\eta} \left( \frac{\tilde{\gamma}_j w_j' L_j'}{P_j'} \right)^{1-\eta} - \frac{\varepsilon}{1+\varepsilon} \left( \tilde{\gamma}_j \frac{w_j'}{P_j'} \right)^{\frac{(1+\varepsilon)(1-\eta)}{1+\eta\varepsilon}} + \frac{\varepsilon}{1+\varepsilon} \left( \tilde{\gamma}_j \frac{w_j}{P_j} \right)^{\frac{(1+\varepsilon)(1-\eta)}{1+\eta\varepsilon}} \right)^{\frac{1}{1-\eta}} P_j}{w_j L_j \tilde{\gamma}_j} - 1 =
\end{aligned}$$

Defining  $\kappa_{jj} \equiv \Pi_{s=1}^S (\lambda_{jj}^s)^{\frac{\gamma^s}{1-\sigma}}$ , we have:

$$\begin{aligned} \hat{W}_j &= (1-\eta)^{\frac{1}{1-\eta}} \frac{\left( \frac{1}{1-\eta} (\tilde{\gamma}_j \kappa'_{jj})^{\frac{(1+\varepsilon)(1-\eta)}{1+\eta\varepsilon}} - \frac{\varepsilon}{1+\varepsilon} (\tilde{\gamma}_j \kappa'_{jj})^{\frac{(1+\varepsilon)(1-\eta)}{1+\eta\varepsilon}} + \frac{\varepsilon}{1+\varepsilon} (\tilde{\gamma}_j \kappa_{jj})^{\frac{(1+\varepsilon)(1-\eta)}{1+\eta\varepsilon}} \right)^{\frac{1}{1-\eta}} P_j}{w_j L_j \tilde{\gamma}_j} - 1 = \\ &= (1-\eta)^{\frac{1}{1-\eta}} (\tilde{\gamma}_j)^{\frac{(1+\varepsilon)}{1+\eta\varepsilon}} (\kappa'_{jj})^{\frac{(1+\varepsilon)}{1+\eta\varepsilon}} \frac{\left( \frac{1}{1-\eta} + \frac{\varepsilon}{1+\varepsilon} \left( (\hat{\kappa}_{jj})^{-\frac{(1+\varepsilon)(1-\eta)}{1+\eta\varepsilon}} - 1 \right) \right)^{\frac{1}{1-\eta}} P_j}{w_j L_j \tilde{\gamma}_j} - 1. \end{aligned}$$

And using again the expression for  $\frac{\tilde{\gamma}_j w_j L_j}{P_j}$ :

$$\begin{aligned} \hat{W}_j &= (1-\eta)^{\frac{1}{1-\eta}} (\tilde{\gamma}_j)^{\frac{(1+\varepsilon)}{1+\eta\varepsilon}} (\kappa'_{jj})^{\frac{(1+\varepsilon)}{1+\eta\varepsilon}} \left( \frac{1}{1-\eta} + \frac{\varepsilon}{1+\varepsilon} \left( (\hat{\kappa}_{jj})^{-\frac{(1+\varepsilon)(1-\eta)}{1+\eta\varepsilon}} - 1 \right) \right)^{\frac{1}{1-\eta}} (\tilde{\gamma}_j \kappa_{jj})^{-\frac{(1+\varepsilon)}{1+\eta\varepsilon}} - 1 = \\ &= (1-\eta)^{\frac{1}{1-\eta}} (\hat{\kappa}_{jj})^{\frac{(1+\varepsilon)}{1+\eta\varepsilon}} \left( \frac{1}{1-\eta} + \frac{\varepsilon}{1+\varepsilon} \left( (\hat{\kappa}_{jj})^{-\frac{(1+\varepsilon)(1-\eta)}{1+\eta\varepsilon}} - 1 \right) \right)^{\frac{1}{1-\eta}} - 1, \end{aligned}$$

which rearranged gives equation (29) ■

**Proposition:** *The gains from trade in a multiple sector model with Armington setting and elastic labor supply are always higher than in a model with fixed labor supply*

**Proof:** We want to show, similarly to proposition 1, that:

$$\varphi (\hat{\kappa}_{jj})^{\frac{(1+\varepsilon)}{1+\eta\varepsilon}} \left( \chi + \pi \left( (\hat{\kappa}_{jj})^{-\frac{(1+\varepsilon)(1-\eta)}{1+\eta\varepsilon}} - 1 \right) \right)^{\frac{1}{1-\eta}} > \hat{\kappa}_{jj}$$

Consider first the case of  $\eta < 1$ . Rearrange the inequality:

$$\varphi^{1-\eta} (\hat{\kappa}_{jj})^{\frac{\varepsilon(1-\eta)^2}{1+\eta\varepsilon}} \left( \chi + \pi \left( (\hat{\kappa}_{jj})^{-\frac{(1+\varepsilon)(1-\eta)}{1+\eta\varepsilon}} - 1 \right) \right) > 1 \implies$$

$$\varphi^{1-\eta} (\hat{\kappa}_{jj})^{\frac{\varepsilon(1-\eta)^2}{1+\eta\varepsilon}} \chi + \varphi^{1-\eta} (\hat{\kappa}_{jj})^{\frac{\varepsilon(1-\eta)^2 - (1+\varepsilon)(1-\eta)}{1+\eta\varepsilon}} \pi > 1 + \varphi^{1-\eta} (\hat{\kappa}_{jj})^{\frac{\varepsilon(1-\eta)^2}{1+\eta\varepsilon}} \pi \implies$$

$$(\hat{\kappa}_{jj})^\rho \chi + (\hat{\kappa}_{jj})^{\rho - \frac{(1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)(1-\sigma)}} \pi > \varphi^{\eta-1} + (\hat{\kappa}_{jj})^\rho \pi$$

where  $\rho \equiv \frac{\varepsilon(1-\eta)^2}{(1+\eta\varepsilon)(1-\sigma)} < 0$  and where we redefined  $\kappa_{jj} \equiv \Pi_{s=1}^S (\lambda_{jj}^s)^{\gamma^s}$ . Since  $\hat{\lambda}_{jj} < 1$  after a

trade liberalization, then  $\hat{\kappa}_{jj} < 1$  and  $(\hat{\kappa}_{jj})^{\rho - \frac{(1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)(1-\sigma)}} > (\hat{\kappa}_{jj})^\rho > 1$ . Rearrange:

$$(\hat{\kappa}_{jj})^\rho (\chi - \pi)\varphi^{1-\eta} + \pi\varphi^{1-\eta} (\hat{\kappa}_{jj})^{\rho - \frac{(1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)(1-\sigma)}} > 1,$$

which always holds if  $\varepsilon > 0$  and  $\eta < 1$ , noting that  $(\chi - \pi)\varphi^{1-\eta} > 0$ . Indeed note that when  $\varepsilon = 0$ , that is the inelastic labor case, we have that  $\rho = 0$  and the LHS is equal to 1. It is then easy to see that the LHS is increasing in  $\varepsilon$ , so the inequality always holds for  $\varepsilon > 0$ . Consider now the case of  $\eta > 1$ . Gains are higher than ACR with multiple sectors if and only if:

$$\varphi (\hat{\kappa}_{jj})^{\frac{(1+\varepsilon)}{1+\eta\varepsilon}} \left( \chi + \pi \left( (\hat{\kappa}_{jj})^{-\frac{(1+\varepsilon)(1-\eta)}{1+\eta\varepsilon}} - 1 \right) \right)^{\frac{1}{1-\eta}} > \hat{\kappa}_{jj} \implies$$

$$\varphi^{1-\eta} (\hat{\kappa}_{jj})^{\frac{\varepsilon(1-\eta)^2}{1+\eta\varepsilon}} \left( \chi + \pi \left( (\hat{\kappa}_{jj})^{-\frac{(1+\varepsilon)(1-\eta)}{1+\eta\varepsilon}} - 1 \right) \right) < 1.$$

Then following the same steps as before:

$$(\hat{\kappa}_{jj})^\rho (\chi - \pi)\varphi^{1-\eta} + \pi\varphi^{1-\eta} (\hat{\kappa}_{jj})^{\rho - \frac{(1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)(1-\sigma)}} < 1$$

which always holds if  $\eta > 1$  and  $\varepsilon > 0$ . ■

**Multiple sectors model - Melitz.** It is easy to prove, similarly to the baseline Melitz model, that the number of entrants in each sector is:

$$J_i^s = \frac{\sigma - 1}{\sigma\theta f_e} L_i^s$$

and the sectoral trade shares are:

$$\lambda_{ij}^s = \frac{(f_{ij}^s)^{\frac{1-\sigma+\theta}{1-\sigma}} L_i^s (w_i \tau_{ij}^s)^{-\theta^s}}{\sum_k (f_{kj}^s)^{\frac{1-\sigma+\theta}{1-\sigma}} L_k^s (w_i \tau_{ij}^s)^{-\theta^s}}.$$

We can find the real wage in the same way as in the baseline model:

$$\frac{w_j}{P_j^s} = (\vartheta_{jj}^s \lambda_{jj}^s)^{\zeta^s},$$

where  $\zeta^s \equiv \frac{(1+\eta\varepsilon)(\sigma-1)}{\theta^s(1+\varepsilon-\sigma(1+\eta\varepsilon))}$  and  $\vartheta_{jj}^s \equiv (f_{jj}^s)^{\frac{1-\sigma+\theta}{1-\sigma}} f_e \frac{\theta-\sigma+1}{(\sigma-1)} \left( \frac{\sigma}{\sigma-1} \right)^\theta \sigma^{\frac{\theta}{\sigma-1}}$ . Raise everything to  $\gamma^s$  and multiply over sectors:

$$\Pi_{s=1}^S (\vartheta_{jj}^s \lambda_{jj}^s)^{\zeta^s \gamma^s} = \Pi_{s=1}^S \left( \frac{w_j^{\gamma^s}}{P_j^{s \gamma^s}} \right) = \frac{w_j}{P_j}.$$

Finally we use the same procedure as for the Armington model to get the equivalent variation as a function of the real wage, then substitute the above equation to get:

$$\begin{aligned} \hat{W}_j &= (1 - \eta)^{\frac{1}{1-\eta}} \frac{\left( \frac{1}{1-\eta} \left( \frac{w' L'}{P'} \right)^{1-\eta} - \frac{L'^{1+1/\varepsilon}}{1+1/\varepsilon} + \frac{L^{1+1/\varepsilon}}{1+1/\varepsilon} \right)^{\frac{1}{1-\eta}} P_j}{w_j L_j} - 1 = \\ &= (1 - \eta)^{\frac{1}{1-\eta}} (\kappa_{jj})^{-\frac{(1+\varepsilon)}{(1+\eta\varepsilon)}} \left( \left( \frac{1}{1-\eta} - \frac{\varepsilon}{1+\varepsilon} \right) (\kappa'_{jj})^{\frac{(1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)}} + \frac{\varepsilon}{1+\varepsilon} (\kappa_{jj})^{\frac{(1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)}} \right)^{\frac{1}{1-\eta}} - 1 = \\ &= (1 - \eta)^{\frac{1}{1-\eta}} (\hat{\kappa}_{jj})^{\frac{(1+\varepsilon)}{(1+\eta\varepsilon)}} \left( \frac{1}{1-\eta} + \frac{\varepsilon}{1+\varepsilon} \left( (\hat{\kappa}_{jj})^{-\frac{(1+\varepsilon)(1-\eta)}{(1+\eta\varepsilon)}} - 1 \right) \right)^{\frac{1}{1-\eta}} - 1 \end{aligned}$$

where  $\kappa_{jj} \equiv \Pi_{s=1}^S (\vartheta_{jj}^s \lambda_{jj}^s)^{\zeta^s \gamma^s}$ . Similarly to the previous proof and the proof of Proposition 2, it is easy to show that gains from trade in the multiple sectors Melitz model are higher than the gains in the multiple sectors ACR only when  $\eta < 1$ .<sup>39</sup>

### Derivations of equilibrium equations for the variable markups model

The FOCs for consumption and labor are:

$$(q + \bar{c})^{-\frac{1}{\sigma}} \left( \int (q + \bar{c})^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma(1-\eta)}{\sigma-1} - 1} = \lambda p_\omega,$$

$$L_j^{1/\varepsilon} = \lambda w_j.$$

The choke price is the reservation price such that the quantity is zero:

$$p_j^* = \frac{1}{\lambda \bar{c}^{1/\sigma} \left( \int (q_\omega + \bar{c})^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{(1-\eta)\sigma}{1-\sigma}}},$$

so the optimal quantity can be rewritten as:

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<sup>39</sup>We omit the complete proof for the sake of brevity.

$$q_\omega = \bar{c} \left( \left( \frac{p_\omega}{p_j^*} \right)^{-\sigma} - 1 \right).$$

By using the FOC for  $q_\omega$ , we can write  $C_j^{-\eta} = \lambda P_j$ , where  $P_j \equiv \left( \int p_\omega^{1-\sigma} d\omega \right)^{\frac{1}{1-\sigma}}$ . Take the ratio of the two FOCs to get:

$$(L_j)^{1/\varepsilon} = C_j^{-\eta} \frac{w_j}{P_j}.$$

Note that using the solution for  $q_\omega$ , we have that:

$$\begin{aligned} C_j &= \left( \sum_i \int_{\omega \in \Omega_{ij}} (q_\omega + \bar{c})^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}} = \\ &= \bar{c} (p_j^*/P_j)^\sigma \end{aligned}$$

Therefore optimal labor is:

$$L_j = \left( \frac{w_j}{P_j} \right)^\varepsilon \left( \frac{p_j^*}{P_j} \right)^{-\sigma\eta\varepsilon} \bar{c}^{-\eta\varepsilon}.$$

The derivation of Equation (33) is the same as in ACDR, so we don't report it here. To derive equation (35), we start from the excess expenditure function:

$$\min \sum_i J_i \int_{z_{ij}^*} p(z, c_{ij}) q(z) f(z) dz - w_j L_j - \xi_j \left[ \frac{1}{1-\eta} \left( \sum_i J_i \int_{z_{ij}^*} u(q_{ij}(z)) f(z) dz \right)^{1-\eta} - v(L_j) - u' \right]$$

We differentiate the above expression by applying the envelope theorem:

$$\begin{aligned} d\ln e_j &= \sum_i \lambda_{ij} d\ln J_i - \sum_i J_i \int_{z_{ij}^*} u(q_{ij}(z)) f(z) dz \left( \sum_i J_i \int_{z_{ij}^*} u(q_{ij}(z)) f(z) dz \right)^{-\eta} \frac{\xi_j}{w_j L_j} d\ln J_i \\ &\quad - \sum_i \lambda_{ij} \left[ \frac{p(z_{ij}^*, c_{ij}) q(z_{ij}^*) - \xi \left( \sum_i J_i \int_{z_{ij}^*} u(q_{ij}(z)) f(z) dz \right)^{-\eta} u(q(z_{ij}^*))}{\int_{z_{ij}^*} p(z, c_{ij}) q_{ij}(z) f(z) dz} \right] f(z_{ij}^*) z_{ij}^* d\ln z_{ij}^* \\ &\quad + \sum_i \lambda_{ij} \left( \int_{z_{ij}^*} \frac{\partial \ln p(z, c_{ij})}{\partial \ln z_{ij}^*} \frac{p(z) q(z) f(z)}{\int_{z_{ij}^*} p(z, c_{ij}) q_{ij}(z) f(z) dz} dz \right) d\ln z_{ij}^* - \frac{d(L)}{wL} + \xi_j \frac{v(L_j)}{w_j L_j} d\ln v(L_j) \end{aligned}$$

$$+ \sum_i \lambda_{ij} \left( \int_{z_{ij}^*} \frac{\partial \ln p(z, c_{ij})}{\partial \ln c_{ij}} \frac{p(z)q(z)f(z)}{\int_{z_{ij}^*} p(z, c_{ij})q_{ij}(z)f(z)dz} dz \right) d \ln c_{ij}.$$

Define  $v \equiv \ln \left( \frac{w_i \tau_{ij}}{\frac{z}{p_j^*}} \right)$  to be a measure of relative efficiency of the firm relative to the market. Following ACDR, the above can be simplified as:

$$d \ln e_j = -V_j \sum_i \lambda_{ij} d \ln J_i + \left( 1 - \frac{\rho}{1 + \theta} \right) \sum_i \lambda_{ij} d \ln c_{ij} - \frac{d(L)}{wL} + \xi_j \frac{v(L_j)}{w_j L_j} d \ln v(L_j),$$

where we define:

$$V_j \equiv \int_0^\infty \left( \frac{u(q(v))\Delta_j}{u'(q(v))q(v)} - 1 \right) \frac{e^{\mu(v) - (\theta+1)v} q(v)}{\int_0^\infty e^{\mu(v') - (\theta+1)v'} q(v') dv'} dv,$$

$$\Delta_j \equiv \left( \sum_i J_i \int_{z_{ij}^*} u(q_{ij}(z)) f(z) dz \right)^{-\eta},$$

$$\rho \equiv \int_0^\infty \frac{\partial \ln \mu(v)}{\partial \ln v} \frac{(\mu(v)/v) e^{d(v)} v^{-\theta-1}}{\int_0^\infty (\mu(v')/v') e^{d(v')} v'^{-\theta-1} dv'} dv.$$

Note that  $\rho$  is a weighted average of markup elasticities, as in ACDR. In the last term, the Lagrange multiplier can be written as:

$$\xi_j = \frac{w}{v'(L)}.$$

from the FOCs of the expenditure minimization problem. Then we have, since the wage is the numeraire:

$$-d \ln L + \frac{w}{v'(L)} \frac{v(L_j)}{w_j L_j} d \ln v(L_j) = -d \ln L + \frac{v(L_j)}{v'(L)L} \frac{1 + \varepsilon}{\varepsilon} d \ln L_j = 0.$$

Since the last two terms are zero, we have the expression in Equation (35). Assuming symmetric countries for simplicity, from Equation (34) we can write:

$$\sum_i \lambda_{ij} d \ln c_{ij} = \frac{d \ln \lambda_{jj}}{\theta},$$

and thus we have:



$$\begin{aligned}
d\ln e_j &= -V_j d\ln J_j + \left(1 - \frac{\rho}{1+\theta}\right) \frac{d\ln \lambda_{jj}}{\theta} = \\
&= -V_j d\ln L_j + \left(1 - \frac{\rho}{1+\theta}\right) \frac{d\ln \lambda_{jj}}{\theta} \\
&= -V_j (\varepsilon d\ln w_j - \sigma\eta\varepsilon d\ln p_j^* - (1 - \sigma\eta)\varepsilon d\ln P) + \left(1 - \frac{\rho}{1+\theta}\right) \frac{d\ln \lambda_{jj}}{\theta}.
\end{aligned}$$

As in ACDR, we can differentiate the trade balance equation to write  $d\ln p_j^* = \frac{\theta}{1+\theta} \frac{d\ln \lambda_{jj}}{\theta}$ , so:

$$= \underbrace{V_j(1 - \sigma\eta)\varepsilon d\ln P}_{\text{distortion}} + \underbrace{V_j \frac{\sigma\eta\varepsilon\theta}{1+\theta} \frac{d\ln \lambda_{jj}}{\theta}}_{\text{entry effect}} + \underbrace{\left(1 - \frac{\rho}{1+\theta}\right) \frac{d\ln \lambda_{jj}}{\theta}}_{\text{ACDR}}.$$

### Algorithm to compute welfare gains in the variable markups model

1. Compute the initial and the counterfactual equilibrium under two vectors of trade costs  $\{\tau_{ij}\}$  and  $\{\tau_{ij}'\}$ .
2. Given  $p_j^*$  and  $w_j$  from the second equilibrium, compute the reservation utility:

$$\bar{u}'_j = \sum_i J'_i \int_{z_{ij}^*}^{\infty} u(q') \theta z^{-\theta-1} dz - \frac{L_j'^{1+1/\epsilon}}{1+1/\epsilon}$$

where  $u(\cdot)$  is the utility function associated with  $d(\cdot)$ .

3. Compute the Lagrange multiplier  $\lambda_j$  associated with the minimization problem, assuming the budget constraint of the expenditure minimization problem binds:

$$\sum_i \int_{z_{ij}^*}^{\infty} u(q(\mu - \nu - \ln \lambda_j)) \theta z_1^{-\theta-1} dz = \bar{u}'_j$$

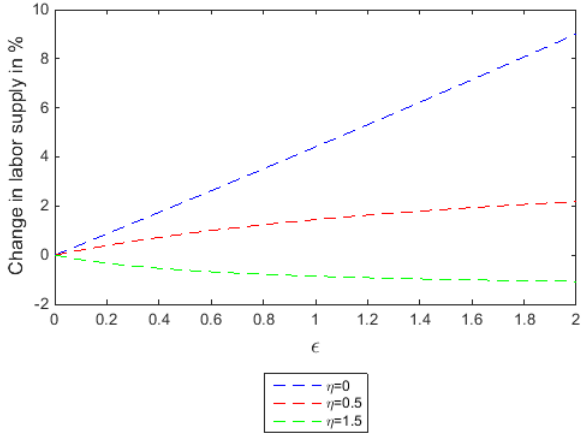
4. Compute the expenditure level required to achieve the same utility as in the second equilibrium. From the expenditure minimization problem,  $e_j(p_{ij}, \bar{u}'_j)$  can be found as:

$$e_j(p_{ij}, \bar{u}'_j) = \sum_i \int_{\Omega_{ij}^*} p_{\omega} q_{\omega}(\lambda_j) d\omega$$

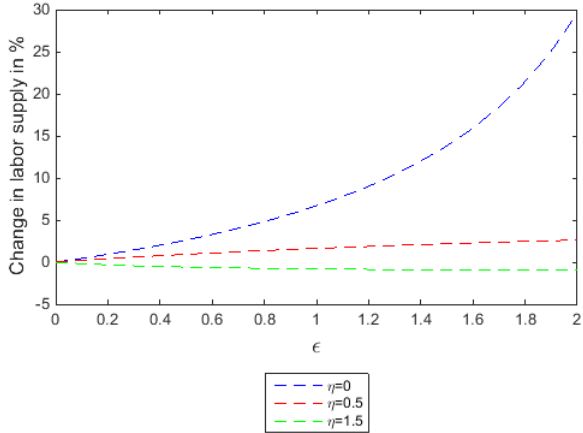
5. Compute the equivalent variation as  $EV = \frac{e_j(p_{ij}, \bar{u}'_j)}{wL} - 1$ .

# Tables and figures

Figure 1: Change in labor supply



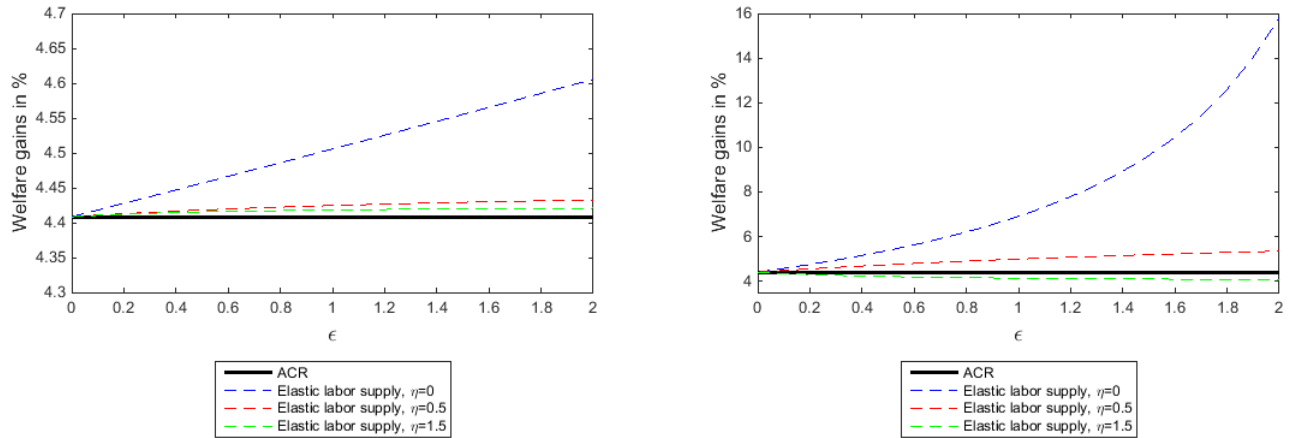
Armington model



Melitz model

Notes: The figures show the change in labor supply after moving from trade costs of  $\tau_{ij} = 1.1$  to free trade for two models: Melitz with elastic labor supply and Armington with elastic labor supply, for different values for  $\eta$ . We set the trade elasticity to 4.

Figure 2: Gains from trade - baseline model

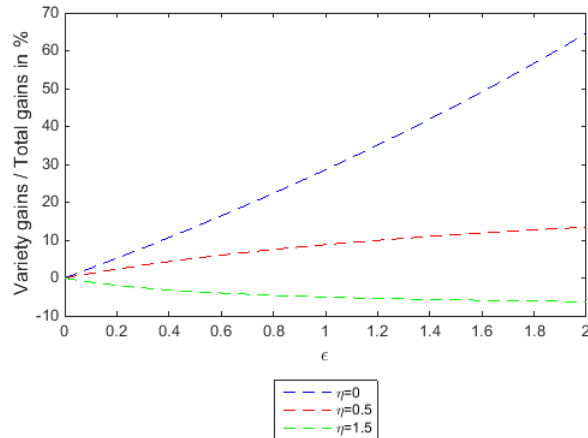


Armington model

Melitz model

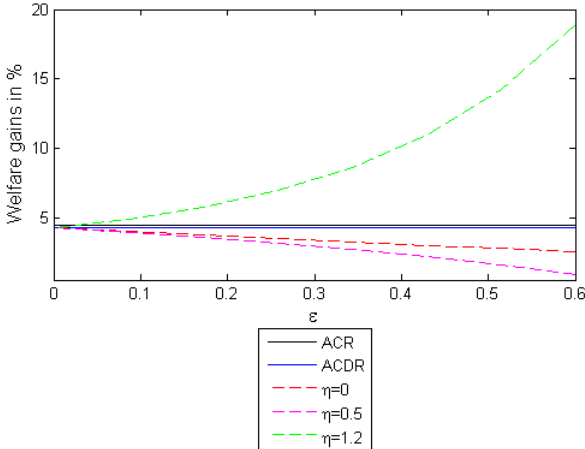
*Notes:* The figures show the change in labor supply after moving from trade costs of  $\tau_{ij} = 1.1$  to free trade for three models: ACR, Melitz with elastic labor supply and Armington with elastic labor supply, for different values for  $\eta$ . We set the trade elasticity to 4.

Figure 3: Gains from variety in the Melitz model



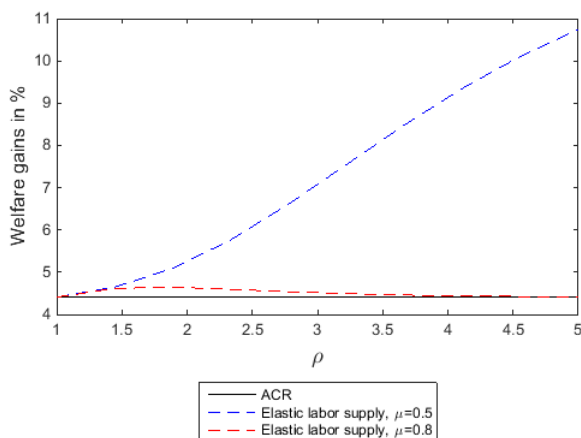
*Notes:* This figure shows, for the Melitz model, the percentage contribution of the gains from variety to the total gains of moving from trade costs of  $\tau_{ij} = 1.1$  to free trade. We set the trade elasticity to 4.

Figure 4: Welfare gains with variable markups

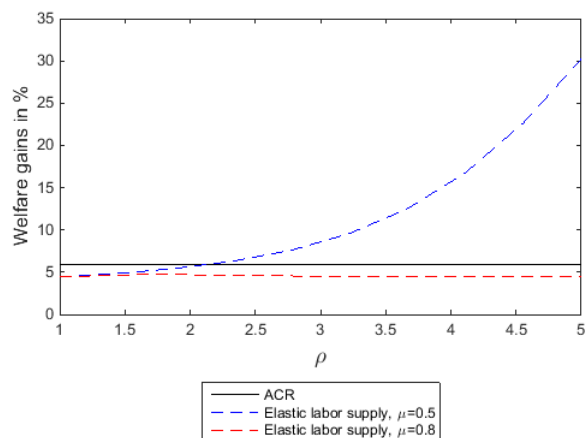


Notes: This figure shows the welfare gains of moving from trade costs of  $\tau_{ij} = 1.1$  to free trade for three models: ACR (CES utility), ACDR (generalized CES) and our model with generalized CES and elastic labor supply, for different values for  $\eta$ . We set the trade elasticity to 4 and  $\bar{c} = 0.5$ .

Figure 5: Gains with non-separable preferences



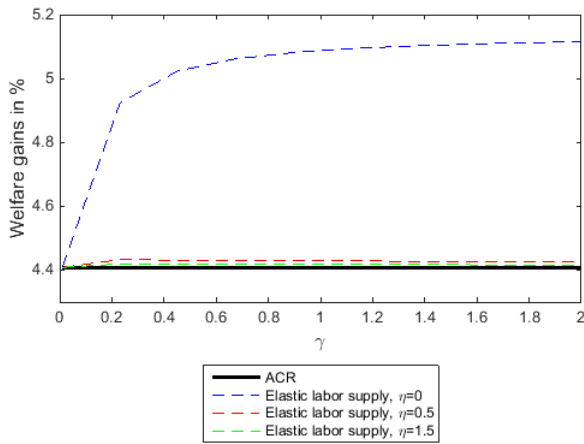
Armington model



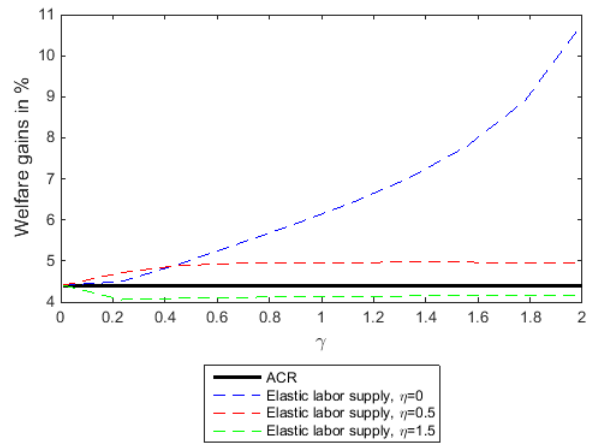
Melitz model

*Notes:* The figures show the welfare gains of moving from trade costs of  $\tau_{ij} = 1.1$  to free trade for three models: ACR, Armington with non-separable preferences and elastic labor supply, and Melitz with non-separable preferences and elastic labor supply, for different values for  $\rho$  and  $\mu$ . We set the trade elasticity to 4.

Figure 6: Gains from trade with alternative utility



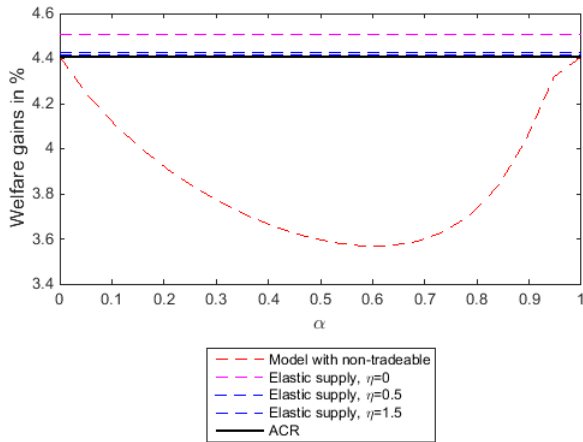
Armington model



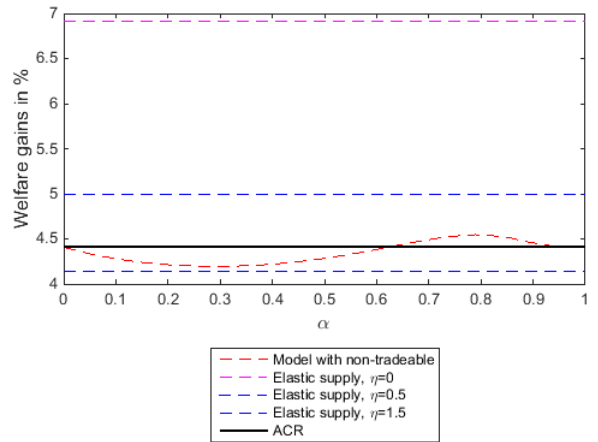
Melitz model

*Notes:* The figures show the gains from trade after moving from trade costs of  $\tau_{ij} = 1.1$  to free trade for three models: ACR, Armington with elastic labor supply and alternative utility function, Melitz with elastic labor supply and alternative utility function, for different values for  $\eta$  and  $\gamma$ . We set the trade elasticity to 4.

Figure 7: Gains from trade with a non-tradeable sector



Armington model



Melitz model

*Notes:* The figures show the gains from trade after moving from trade costs of  $\tau_{ij} = 1.1$  to free trade for several models. In the left figure we plot gains for ACR, Armington with elastic labor supply for different values for  $\eta$  and  $\varepsilon$  such that the compensated elasticity is 0.5, and Armington with fixed labor supply and a non-tradeable sector. In the right figure we do the same but for the Melitz model. We set the trade elasticity to 4.

Table 1: Gains from trade,  $\eta = 0.1$ 

Country	ONE SECTOR			MULTIPLE SECTORS		
	Elastic supply Armington	Elastic supply Melitz	ACR	Elastic supply Armington	Elastic supply Melitz	ACR
AUS	3.00%	3.54%	2.98%	9.60%	11.42%	9.42%
AUT	7.66%	9.09%	7.54%	47.06%	58.16%	43.48%
BEL	10.43%	12.42%	10.22%	53.16%	66.05%	48.69%
BRA	1.92%	2.26%	1.91%	3.87%	4.57%	3.84%
CAN	4.97%	5.88%	4.92%	21.88%	26.39%	21.02%
CHN	3.43%	4.06%	3.41%	4.20%	4.96%	4.16%
CZE	8.16%	9.70%	8.03%	20.97%	25.26%	20.17%
DEU	5.95%	7.05%	5.88%	14.93%	17.87%	14.51%
DNK	7.80%	9.27%	7.68%	46.71%	57.70%	43.17%
ESP	4.05%	4.79%	4.02%	10.10%	12.02%	9.90%
FIN	5.86%	6.94%	5.79%	12.81%	15.30%	12.50%
FRA	3.89%	4.60%	3.86%	10.65%	12.68%	10.43%
GBR	4.23%	5.00%	4.19%	15.24%	18.25%	14.80%
GRC	5.57%	6.60%	5.51%	20.20%	24.32%	19.45%
HUN	11.36%	13.54%	11.11%	45.85%	56.60%	42.42%
IDN	3.78%	4.47%	3.75%	5.86%	6.94%	5.79%
IND	3.07%	3.62%	3.05%	4.88%	5.77%	4.83%
IRL	11.28%	13.45%	11.04%	32.58%	39.73%	30.76%
ITA	3.76%	4.44%	3.73%	9.71%	11.56%	9.53%
JPN	2.16%	2.55%	2.15%	1.46%	1.73%	1.46%
KOR	5.72%	6.77%	5.65%	4.11%	4.86%	4.08%
MEX	4.32%	5.11%	4.28%	12.84%	15.33%	12.53%
NLD	8.41%	9.99%	8.27%	34.03%	41.54%	32.05%
POL	5.80%	6.87%	5.73%	23.52%	28.42%	22.53%
PRT	5.85%	6.93%	5.79%	33.16%	40.46%	31.28%
ROM	5.94%	7.04%	5.87%	22.46%	27.10%	21.55%
RUS	3.11%	3.67%	3.09%	22.86%	27.60%	21.92%
SVK	10.65%	12.68%	10.43%	30.07%	36.57%	28.49%
SVN	9.42%	11.21%	9.25%	73.46%	92.80%	65.53%
SWE	6.79%	8.05%	6.70%	14.64%	17.52%	14.24%
TUR	3.73%	4.41%	3.71%	13.92%	16.65%	13.56%
TWN	8.33%	9.89%	8.19%	10.85%	12.93%	10.63%
USA	2.26%	2.67%	2.25%	4.67%	5.53%	4.63%
RoW	7.04%	8.36%	6.95%	18.54%	22.28%	17.91%
<b>Average</b>	5.87%	6.97%	5.79%	20.91%	25.50%	19.74%
<b>Median</b>	5.76%	6.82%	5.69%	15.08%	18.06%	14.66%

*Notes:* The table shows the gains from trade in the counterfactual exercise for the elastic labor supply model and for ACR, for the one sector and for the multiple sectors models, and for both market settings. All data is from WIOD for the year 2008. We set the trade elasticity to 4 in all models,  $\eta = 0.1$  and  $\varepsilon = 0.53$ , to match an aggregate compensated elasticity of 0.5, as in Chetty (2012).



Table 2: Change in labor supply,  $\eta = 0.1$

Country	ONE SECTOR		MULTIPLE SECTORS	
	Armington	Melitz	Armington	Melitz
AUS	1.25%	4.24%	1.47%	5.03%
AUT	2.84%	19.56%	3.34%	23.81%
BEL	3.63%	21.91%	4.27%	26.76%
BRA	0.82%	1.73%	0.97%	2.04%
CAN	1.97%	9.46%	2.31%	11.32%
CHN	1.41%	1.87%	1.66%	2.21%
CZE	2.99%	9.08%	3.52%	10.86%
DEU	2.30%	6.53%	2.70%	7.78%
DNK	2.88%	19.43%	3.39%	23.64%
ESP	1.64%	4.46%	1.93%	5.29%
FIN	2.27%	5.63%	2.67%	6.69%
FRA	1.58%	4.69%	1.86%	5.57%
GBR	1.70%	6.66%	2.00%	7.94%
GRC	2.17%	8.75%	2.56%	10.47%
HUN	3.87%	19.09%	4.55%	23.22%
IDN	1.54%	2.61%	1.81%	3.08%
IND	1.27%	2.17%	1.50%	2.57%
IRL	3.85%	13.84%	4.53%	16.69%
ITA	1.53%	4.29%	1.80%	5.09%
JPN	0.92%	0.66%	1.08%	0.77%
KOR	2.22%	1.84%	2.61%	2.17%
MEX	1.74%	5.64%	2.04%	6.70%
NLD	3.06%	14.42%	3.60%	17.41%
POL	2.25%	10.14%	2.64%	12.15%
PRT	2.27%	14.07%	2.67%	16.98%
ROM	2.30%	9.70%	2.70%	11.61%
RUS	1.29%	9.86%	1.52%	11.81%
SVK	3.68%	12.82%	4.34%	15.44%
SVN	3.35%	29.49%	3.95%	36.42%
SWE	2.57%	6.41%	3.02%	7.63%
TUR	1.52%	6.10%	1.79%	7.26%
TWN	3.04%	4.78%	3.58%	5.68%
USA	0.96%	2.08%	1.13%	2.46%
RoW	2.65%	8.06%	3.12%	9.62%
<b>Average</b>	2.22%	8.88%	2.61%	10.71%
<b>Median</b>	2.23%	6.60%	2.63%	7.86%

*Notes:* The table shows the change in labor supply in the counterfactual exercise, for the one sector and for the multiple sectors models, and for both market settings. All data is from WIOD for the year 2008. We set the trade elasticity to 4 in all models,  $\eta = 0.1$  and  $\varepsilon = 0.53$ , to match an aggregate compensated elasticity of 0.5, as in Chetty (2012).

Table 3: Gains from trade,  $\eta = 0.5$ 

Country	ONE SECTOR			MULTIPLE SECTORS		
	Elastic supply Armington	Elastic supply Melitz	ACR	Elastic supply Armington	Elastic supply Melitz	ACR
AUS	2.99%	3.26%	2.98%	9.47%	10.38%	9.42%
AUT	7.58%	8.30%	7.54%	44.60%	49.64%	43.48%
BEL	10.29%	11.28%	10.22%	50.08%	55.86%	48.69%
BRA	1.91%	2.09%	1.91%	3.85%	4.20%	3.84%
CAN	4.94%	5.40%	4.92%	21.29%	23.46%	21.02%
CHN	3.42%	3.74%	3.41%	4.17%	4.56%	4.16%
CZE	8.07%	8.84%	8.03%	20.42%	22.49%	20.17%
DEU	5.90%	6.46%	5.88%	14.64%	16.09%	14.51%
DNK	7.72%	8.45%	7.68%	44.27%	49.27%	43.17%
ESP	4.03%	4.40%	4.02%	9.96%	10.92%	9.90%
FIN	5.81%	6.36%	5.79%	12.60%	13.83%	12.50%
FRA	3.87%	4.23%	3.86%	10.50%	11.51%	10.43%
GBR	4.20%	4.59%	4.19%	14.94%	16.42%	14.80%
GRC	5.53%	6.05%	5.51%	19.68%	21.68%	19.45%
HUN	11.19%	12.27%	11.11%	43.49%	48.39%	42.42%
IDN	3.76%	4.11%	3.75%	5.81%	6.36%	5.79%
IND	3.05%	3.34%	3.05%	4.85%	5.30%	4.83%
IRL	11.12%	12.19%	11.04%	31.33%	34.68%	30.76%
ITA	3.74%	4.09%	3.73%	9.59%	10.51%	9.53%
JPN	2.15%	2.35%	2.15%	1.46%	1.59%	1.46%
KOR	5.67%	6.20%	5.65%	4.09%	4.47%	4.08%
MEX	4.29%	4.69%	4.28%	12.62%	13.86%	12.53%
NLD	8.32%	9.11%	8.27%	32.66%	36.18%	32.05%
POL	5.75%	6.29%	5.73%	22.84%	25.19%	22.53%
PRT	5.81%	6.35%	5.79%	31.86%	35.28%	31.28%
ROM	5.89%	6.45%	5.87%	21.83%	24.07%	21.55%
RUS	3.10%	3.38%	3.09%	22.21%	24.49%	21.92%
SVK	10.50%	11.51%	10.43%	28.98%	32.05%	28.49%
SVN	9.31%	10.20%	9.25%	68.02%	76.37%	65.53%
SWE	6.73%	7.36%	6.70%	14.36%	15.78%	14.24%
TUR	3.71%	4.06%	3.71%	13.67%	15.01%	13.56%
TWN	8.23%	9.02%	8.19%	10.70%	11.73%	10.63%
USA	2.26%	2.46%	2.25%	4.64%	5.08%	4.63%
RoW	6.98%	7.64%	6.95%	18.11%	19.93%	17.91%
<b>Average</b>	5.82%	6.37%	5.79%	20.11%	22.25%	19.74%
<b>Median</b>	5.71%	6.25%	5.69%	14.79%	16.25%	14.66%

*Notes:* The table shows the gains from trade in the counterfactual exercise for the elastic labor supply model and for ACR, for the one sector and for the multiple sectors models, and for both market settings. All data is from WIOD for the year 2008. We set the trade elasticity to 4 in all models,  $\eta = 0.5$  and  $\varepsilon = 0.67$ , to match a compensated elasticity of 0.5, as in Chetty (2012).

Table 4: Decomposition of the gains from trade,  $\eta = 0$ 

<b>Country</b>	Total gains	ACR	Supply effect	Entry effect	Consumption effect	Leisure effect
AUS	3.62%	2.98%	1.23%	1.22%	5.43%	-1.81%
AUT	9.32%	7.54%	3.27%	3.17%	13.99%	-4.66%
BEL	12.77%	10.22%	4.55%	4.38%	19.15%	-6.38%
BRA	2.31%	1.91%	0.78%	0.78%	3.47%	-1.16%
CAN	6.02%	4.92%	2.07%	2.04%	9.03%	-3.01%
CHN	4.15%	3.41%	1.42%	1.40%	6.22%	-2.07%
CZE	9.95%	8.03%	3.50%	3.39%	14.92%	-4.97%
DEU	7.22%	5.88%	2.50%	2.45%	10.83%	-3.61%
DNK	9.50%	7.68%	3.33%	3.24%	14.25%	-4.75%
ESP	4.90%	4.02%	1.68%	1.65%	7.34%	-2.45%
FIN	7.11%	5.79%	2.46%	2.41%	10.66%	-3.55%
FRA	4.71%	3.86%	1.61%	1.59%	7.06%	-2.35%
GBR	5.11%	4.19%	1.75%	1.73%	7.67%	-2.56%
GRC	6.76%	5.51%	2.34%	2.29%	10.14%	-3.38%
HUN	13.92%	11.11%	4.99%	4.78%	20.88%	-6.96%
IDN	4.57%	3.75%	1.56%	1.54%	6.85%	-2.28%
IND	3.70%	3.05%	1.26%	1.25%	5.55%	-1.85%
IRL	13.83%	11.04%	4.95%	4.75%	20.74%	-6.91%
ITA	4.54%	3.73%	1.55%	1.53%	6.81%	-2.27%
JPN	2.60%	2.15%	0.88%	0.87%	3.90%	-1.30%
KOR	6.93%	5.65%	2.40%	2.35%	10.40%	-3.47%
MEX	5.23%	4.28%	1.79%	1.76%	7.84%	-2.61%
NLD	10.26%	8.27%	3.61%	3.50%	15.38%	-5.13%
POL	7.03%	5.73%	2.44%	2.38%	10.55%	-3.52%
PRT	7.10%	5.79%	2.46%	2.41%	10.65%	-3.55%
ROM	7.21%	5.87%	2.50%	2.44%	10.82%	-3.61%
RUS	3.75%	3.09%	1.28%	1.26%	5.63%	-1.88%
SVK	13.03%	10.43%	4.65%	4.47%	19.55%	-6.52%
SVN	11.51%	9.25%	4.08%	3.94%	17.27%	-5.76%
SWE	8.26%	6.70%	2.88%	2.80%	12.38%	-4.13%
TUR	4.51%	3.71%	1.54%	1.52%	6.77%	-2.26%
TWN	10.15%	8.19%	3.57%	3.46%	15.23%	-5.08%
USA	2.73%	2.25%	0.92%	0.92%	4.09%	-1.36%
RoW	8.57%	6.95%	2.99%	2.91%	12.85%	-4.28%
<b>Average</b>	7.14%	5.79%	2.49%	2.43%	10.72%	-3.57%
<b>Median</b>	6.98%	5.69%	2.42%	2.37%	10.48%	-3.49%

*Notes:* The table decomposes the gains from trade for the Melitz version of our elastic labor supply model, for  $\eta = 0$ . The first column, total gains, is the sum of columns 2, 3, 4 and 6. Column 5 is the sum of columns 2, 3 and 4. All data is from WIOD for the year 2008. We set the trade elasticity to 4 and  $\varepsilon = 0.5$ , to match a compensated elasticity of 0.5, as in Chetty (2012). Numbers are in percentage points.