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### **Globalization and Individual Gains from Trade**

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**Abstract:**

We analyze the impact of globalization on individual gains from trade in a general equilibrium model of monopolistic competition featuring product diversity, pro-competitive effects and income heterogeneity between and within countries. We show that, although trade reduces markups in both countries, its impact on variety depends on their relative position in the world income distribution: product diversity in the lower income country always expands, while that in the higher income country may shrink. When the latter occurs, the richer consumers in the higher income country may lose from trade because the relative importance of variety versus quantity increases with income. We illustrate this effect using data on GDP per capita and population for 186 countries, as well as parameter estimates for domestic income distributions. Our results suggest that U.S. trade with countries of similar GDP per capita makes all agents in both countries better off, whereas trade with countries having lower GDP per capita may adversely affect up to 11% of the U.S. population.

**Keywords:** Income heterogeneity, product diversity, pro-competitive effects, general equilibrium, monopolistic competition

**JEL Classification:** D43, F12, F15

# 1 Introduction

The questions of whether there are gains from trade and how these gains are distributed are two of the oldest, and most fundamental ones, in international economics. As is well known, trade alters the distribution of income across some broad ‘classes’ such as workers and the owners of capital (Jones, 1965). Trade also adversely affects the owners of resources that are specific to import-competing sectors (Jones, 1971). While it is, therefore, possible that trade hurts particular groups, the fundamental insight advocated by economists is that, under the assumption of perfect markets, the nation as a whole unambiguously gains. Such gains from trade *at the aggregate level* have also been largely confirmed under imperfect competition where product diversity and scale economies matter (Helpman and Krugman, 1985, Ch.9).<sup>1</sup>

Do these aggregate gains from trade, which theoretically make possible a Pareto-improving redistribution, constitute a relevant welfare criterion for globalization? The answer is likely to be negative. Globalization, as Stiglitz (2006, p.63) puts it, “only promises that the country as a whole will benefit. Theory predicts that there will be losers. In principle, the winners could compensate the losers; in practice, this almost never happens.” Given that compensation mechanisms are unlikely to be operational, gains from trade should be assessed *at the individual level*. The relevant criterion is then whether aggregating individual preferences for trade, not aggregating individual gains, leads to globalization. The answer clearly depends on the fraction of agents who gain from trade, irrespective of the magnitude of aggregate gains.

We explore the impact of globalization on individual gains from trade in a general equilibrium model of monopolistic competition building on Behrens and Murata (2007). There are two crucial ingredients in the model. First, we consider that workers are heterogeneous in terms of labor efficiency and, therefore, in terms of income, both between and within countries. Second, we focus on a variable elasticity of substitution (VES) case because, unlike in the constant elasticity of substitution (CES) case, the relative importance of variety versus quantity changes with income. Within such a framework, individual gains from trade can be decomposed into those due to product diversity and those due to pro-competitive effects. In order to focus entirely on these two aspects, we abstract from comparative advantage and income distribution across factors by considering a setting with a single production factor.

Our main results may be summarized as follows. First, in the presence of income heterogeneity between countries, the impact of trade on variety depends on their relative position in the *world income distribution*. In the lower income country, product diversity in consumption always expands, whereas it may shrink in the higher income country. Second, trade always reduces markups in both countries.<sup>2</sup> Consequently, all individuals in the lower income country

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<sup>1</sup>Helpman and Krugman (1985) derive the general result that there are gains from trade: (i) when free trade income and prices enable the economy to purchase autarky aggregate consumption quantities; and (ii) when switching from autarky to free trade expands product diversity in consumption.

<sup>2</sup>This is true even when there is a variety loss in the higher income country because globalization has two

always gain from trade because of lower markups and greater product diversity in consumption. Turning to the higher income country, two cases may arise. First, when its trading partner has sufficiently similar average income, the range of varieties expands and markups fall, thus benefiting all consumers. Second, when its trading partner has sufficiently lower average income, the range of varieties shrinks, while markups fall. In the latter case, whether individuals in the higher income country gain or not depends on their position in the *domestic income distribution*.

We show that it is the richer consumers in the higher income country who may lose from trade because the relative importance of variety versus quantity increases with income. The intuition is that since utility is bounded for each variety in our framework, the richer consumers benefit only little from increased quantity due to a fall in the price-wage ratios, whereas a decrease in product diversity hurts them. On the contrary, lower income consumers care less about variety but more about quantity, and they gain from trade even when facing less product diversity because the lower price-wage ratios allow them to consume more of each variety. Our result thus suggests that measured income inequality under a trade regime may overstate ‘real’ inequality, as the former neglects the different trade-offs between variety and quantity faced by high and low income consumers. This is reminiscent of recent work by Broda and Romalis (2009), who show that much of the rise in measured U.S. income inequality is offset by a relative decline in the prices of products that low income consumers buy.

We finally illustrate how many individuals in the higher income country are likely to lose from trade. Using data on GDP per capita and population for 186 countries, as well as parameter estimates for domestic income distributions, we show that U.S. intra-industry trade with countries of similar GDP per capita makes all agents in both countries better off, whereas U.S. intra-industry trade with countries having lower GDP per capita may adversely affect up to 11% of the U.S. population.<sup>3</sup>

The remainder of the paper is organized as follows. Section 2 briefly reviews the related literature. Section 3 presents the model and derives the equilibrium conditions. Section 4 focuses on the case of homogeneous populations within each country. This allows to build intuition for a more general case of heterogeneous populations between and within countries. Section 5 analyzes the general case and provides some numerical illustrations. Section 6 concludes.

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opposite effects on markups. First, the variety loss under free trade reduces competition, thus raising markups. Second, firms in the higher income country face lower average income under free trade than in autarky, which makes demand more elastic, thus reducing markups. The latter effect always dominates the former in our framework, so that markups fall when switching from autarky to trade.

<sup>3</sup>One may think of relatively new OECD member countries. Indeed, recent work by the OECD (2002, p.161) classifies Czech Republic, Slovak Republic, Mexico, Hungary and Germany, the United States, Poland as countries with “high and increasing intra-industry trade”. This suggests that the set of countries with high intra-industry trade is becoming more dissimilar in terms of GDP per capita.

## 2 Related literature

Recent empirical research in international trade has substantiated the importance of product diversity and pro-competitive effects. Using extremely disaggregated data, Broda and Weinstein (2006) document that the number of U.S. import varieties rose by 212% between 1972 and 2001, which maps into U.S. welfare gains of about 2.6%. Badinger (2007) finds solid evidence that the Single Market Programme of the EU has reduced markups by 26% in aggregate manufacturing of 10 member states. See also Levinsohn (1993), Harrison (1994) and Tybout (2003) for earlier empirical evidence on pro-competitive effects of international trade.

Despite such empirical evidence, theoretical research has not explored how individual welfare is affected by the relative importance of product diversity and pro-competitive effects. Instead, the seminal work by Mayer (1984), for instance, analyzes how the difference in capital endowments across individuals maps into individual preferences for trade openness via changes in factor prices as implied by the Stolper-Samuelson theorem. This prediction under perfect competition has been recently examined and confirmed by using individual survey data (e.g., Balistreri, 1997; Scheve and Slaughter, 2001; Hamilton, 2004; Mayda and Rodrik, 2005).

On the contrary, the monopolistic competition literature focuses either or both on product diversity and pro-competitive effects, without taking into account income heterogeneity (Krugman 1979, 1980). One notable exception is Krugman (1981) who considers a two-factor two-sector monopolistic competition model without intersectoral factor mobility. Since countries differ in relative factor endowments, not only product diversity but also factor prices determine whether each factor gains or not. However, there is no income heterogeneity within each factor and pro-competitive effects do not arise due to the constant elasticity specification.

In this paper, we show that when income heterogeneity and variable demand elasticity are jointly taken into account, trade may reduce product diversity in consumption.<sup>4</sup> This has important welfare implications because individual gains from trade depend on product diversity and pro-competitive effects. Saint-Paul (2006) also uses a variable elasticity model and analyzes the impact of globalization on wages when the total mass of firms is exogenously given and when there is no income heterogeneity within each country. Since our model allows for free entry and exit and income heterogeneity both between and within countries, we can analyze more precisely how the relative importance of variety and quantity affects individual welfare.

Finally, Flam and Helpman (1987) and Stokey (1991) consider the relative importance of quality and quantity. Although this literature on vertical product differentiation essentially deals with the patterns of consumption and specialization, we investigate the impact of trade on individual welfare in the presence of income heterogeneity between and within countries. The related paper by Matsuyama (2000) puts more emphasis on demand complementarities and multisectoral issues under perfect competition, whereas we focus on individual gains from

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<sup>4</sup>Note that this possibility arises even when the number of import varieties increases because the number of domestic varieties decreases when switching from autarky to trade.

trade through product diversity and pro-competitive effects under monopolistic competition.

### 3 Model

Consider a world with two countries, labeled  $r = H, F$ . Variables associated with each country will be subscripted accordingly.<sup>5</sup> Each country is endowed with a mass  $L_r$  of population. Let  $L \equiv L_H + L_F$  denote the world population, and let  $\theta \equiv L_H/L$  stand for the population share of country  $H$ . We assume that labor is the only factor of production and that it is internationally immobile. Furthermore, the labor efficiency may differ both between and within countries. We denote by  $G_r$  the cumulative distribution function and by  $g_r$  the density function of labor efficiency in country  $r$ . Both are assumed to be continuously differentiable, with support  $[0, \infty)$ . An individual with labor efficiency  $h_r$  supplies inelastically that many units of labor. The aggregate labor supply in country  $r$  is then given by  $L_r \bar{h}_r$ , where  $\bar{h}_r \equiv \int h_r dG_r(h_r)$  is the average labor efficiency in that country.

#### 3.1 Preferences

There is a single monopolistically competitive industry producing a continuum of varieties of a horizontally differentiated consumption good. Let  $\Omega_r$  denote the set of varieties produced in country  $r$ , with measure  $n_r$ . Hence,  $N \equiv n_r + n_s$  stands for the endogenously determined mass of varieties in the global economy. Following Behrens and Murata (2007), we assume that preferences are additively separable over varieties and that the subutility functions are of the ‘constant absolute risk aversion’ (CARA) type:

$$\begin{aligned} \max \quad & U_r \equiv \int_{\Omega_r} [1 - e^{-\alpha q_{rr}(i)}] di + \int_{\Omega_s} [1 - e^{-\alpha q_{sr}(j)}] dj \\ \text{s.t.} \quad & \int_{\Omega_r} p_r(i) q_{rr}(i) di + \int_{\Omega_s} p_s(j) q_{sr}(j) dj = E_r(h_r), \end{aligned}$$

where  $p_r(i)$  and  $p_s(j)$  stand for the prices of varieties  $i$  and  $j$  produced in countries  $r$  and  $s$ ;<sup>6</sup>  $q_{rr}(i)$  and  $q_{sr}(j)$  stand for the consumption of domestic and foreign varieties in country  $r$ ;  $E_r(h_r)$  stands for expenditure; and  $\alpha > 0$  is a parameter. The individual with labor efficiency  $h_r$  spends  $E_r(h_r) \equiv w_r h_r + \Pi/L$ , where  $w_r$  stands for the wage rate in country  $r$  and  $\Pi/L$  stands for the identical claim to aggregate profits across individuals.<sup>7</sup>

<sup>5</sup>To reduce the notational burden, we present a two-country version of the model. However, the model can be extended to an arbitrary number of countries without qualitatively affecting our results.

<sup>6</sup>We assume that there are no impediments to trade and that product markets are integrated, i.e., firms cannot price discriminate across markets. This explains why there is only a single subscript for prices.

<sup>7</sup>Since our focus is not on the sources of income heterogeneity, we assume that it is solely driven by the difference in labor efficiency, not by the difference in profit claims. The assumption of equal profit claims entails no loss of generality as each firm is negligible and earns zero profit in equilibrium under free entry and exit.

As shown in Appendix A, the demand functions in country  $r$  at an interior solution are given as follows:

$$q_{rr}(i, h_r) = \frac{E_r(h_r)}{P} - \frac{1}{\alpha P} \left\{ \int_{\Omega_r} \ln \left[ \frac{p_r(i)}{p_r(j)} \right] p_r(j) dj + \int_{\Omega_s} \ln \left[ \frac{p_r(i)}{p_s(j)} \right] p_s(j) dj \right\}, \quad (1)$$

$$q_{sr}(j, h_r) = \frac{E_r(h_r)}{P} - \frac{1}{\alpha P} \left\{ \int_{\Omega_r} \ln \left[ \frac{p_s(j)}{p_r(i)} \right] p_r(i) di + \int_{\Omega_s} \ln \left[ \frac{p_s(j)}{p_s(i)} \right] p_s(i) di \right\}, \quad (2)$$

where  $P \equiv \int_{\Omega_r} p_r(k) dk + \int_{\Omega_s} p_s(k) dk$ . Because marginal utility at zero consumption is finite, demands need not be strictly positive in equilibrium. In Section 3.3.2, we derive a sufficient condition for the price equilibrium to be symmetric, which then makes sure that (1) and (2) hold since the solution will be interior.

Finally, because of the continuum assumption, changes in an individual price have no impact on the price aggregates, so that the own-price derivatives are as follows:

$$\frac{\partial q_{rr}(i, h_r)}{\partial p_r(i)} = -\frac{1}{\alpha p_r(i)} \quad \text{and} \quad \frac{\partial q_{sr}(j, h_r)}{\partial p_s(j)} = -\frac{1}{\alpha p_s(j)}. \quad (3)$$

## 3.2 Technology

All firms have access to the same increasing returns to scale technology. To produce  $Q(i)$  units of any variety requires  $cQ(i) + f$  units of labor, where  $c$  and  $f$  denote the marginal and the fixed labor requirements, respectively. We assume that firms can costlessly differentiate their products and that there are no scope economies. Thus, there is a one-to-one correspondence between firms and varieties, so that the mass of varieties  $N$  also stands for the mass of firms operating in the global economy. There is free entry and exit in each country, which implies that  $n_r$  and  $n_s$  are endogenously determined by the zero profit conditions. The profit of firm  $i$  in country  $r$  is given by:

$$\Pi_r(i) = [p_r(i) - cw_r] Q_r(i) - fw_r, \quad (4)$$

where  $Q_r(i) \equiv L_r \int q_{rr}(i, h_r) dG_r(h_r) + L_s \int q_{rs}(i, h_s) dG_s(h_s)$  stands for its output.

## 3.3 Equilibrium

### 3.3.1 Definition

Each firm in country  $r$  maximizes its profit (4) with respect to  $p_r(i)$ , taking the couples  $(n_H, n_F)$  and  $(w_H, w_F)$  of firm distributions and factor prices as given. Rearranging terms, the first-order conditions can be expressed as follows:

$$\frac{\partial \Pi_r(i)}{\partial p_r(i)} = Q_r(i) - \frac{L [p_r(i) - cw_r]}{\alpha p_r(i)} = 0. \quad (5)$$

Expression (5) highlights a fundamental property of monopolistic competition: although each firm is negligible to the market, it must take into account the pricing decisions of the other

firms since the price aggregates affect its first-order condition. A *price equilibrium* is a price distribution satisfying condition (5) for all firms in countries  $H$  and  $F$ . An *equilibrium* is a price equilibrium and couples  $(n_H, n_F)$  and  $(w_H, w_F)$  of a firm distribution and factor prices such that national factor markets clear, trade is balanced, and firms earn zero profits. Formally, an equilibrium is a solution to the following three conditions:

$$\int_{\Omega_H} [cQ_H(i) + f] di = L_H \int h_H dG_H(h_H), \quad (6)$$

$$\int_{\Omega_F} [cQ_F(j) + f] dj = L_F \int h_F dG_F(h_F), \quad (7)$$

$$L_H \int \int_{\Omega_F} p_F(j) q_{FH}(j, h_H) dj dG_H(h_H) = L_F \int \int_{\Omega_H} p_H(i) q_{HF}(i, h_F) di dG_F(h_F), \quad (8)$$

where all quantities are evaluated at a price equilibrium. One may set either  $w_H$  or  $w_F$  as the numeraire. However, we need not do so since the model is fully determined in real terms.<sup>8</sup> Finally, it can be readily verified that firms earn zero profits when conditions (6)–(8) hold. Hence, aggregate profits are zero and the expenditure of an individual with labor efficiency  $h_r$  is solely given by wage income:  $E_r(h_r) = w_r h_r$ .

### 3.3.2 Properties

In general equilibrium models of imperfect competition, the existence, the uniqueness, and the properties of the price equilibria are usually difficult to establish. The reason is that when firms have an influence on market aggregates, reaction functions can be badly behaved (Roberts and Sonnenschein, 1977). This problem does not occur in continuum models of monopolistic competition because firms have no influence on market aggregates.<sup>9</sup> However, two additional questions arise in our open economy model with income heterogeneity and finite marginal utility at zero consumption: (i) under which conditions the price equilibrium is symmetric; and (ii) under which conditions product and factor prices are equalized under free trade. Note that the answers to these questions are not trivial. Indeed, some firms may find it profitable to deviate from symmetric pricing by charging higher prices to higher income consumers while excluding lower income consumers. Furthermore, firms sell differentiated varieties, so that product price equalization (PPE) and factor price equalization (FPE) need not hold under free trade, even if many studies assume, rather than prove, that this is the case.

In what follows, we first show that free trade leads to both PPE and FPE provided each individual consumes all varieties. We then derive a sufficient condition for this to hold.

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<sup>8</sup>The choice of the numeraire is immaterial in our monopolistic competition framework. This is an important departure from general equilibrium oligopoly models, where the choice of the numeraire is not always neutral (Gabszewicz and Vial, 1972).

<sup>9</sup>In a similar spirit, to ensure the existence of a general equilibrium under oligopolistic competition, Neary (2003) considers a model with a continuum of sectors, in which firms are large in their own sector but negligible in the whole economy.



**Proposition 1** *Assume that each individual consumes all varieties. Then, free trade leads to product and factor price equalization. Furthermore, the product price is uniquely given by*

$$p = cw + \frac{\alpha \bar{E}}{N} \quad \text{where} \quad \bar{E} \equiv \theta \int E_H(h_H) dG_H(h_H) + (1 - \theta) \int E_F(h_F) dG_F(h_F). \quad (9)$$

**Proof.** See Appendix B. ■

As can be seen from (9), there are pro-competitive effects, i.e., the profit-maximizing price is decreasing in the mass of competing firms. Furthermore, it is increasing in the average expenditure  $\bar{E}$ .<sup>10</sup> Since FPE implies that  $\bar{E} = w\bar{h}$ , where  $\bar{h} \equiv \theta\bar{h}_H + (1 - \theta)\bar{h}_F$  denotes the world average labor efficiency, the product price can be rewritten as

$$p = \left(1 + \frac{\alpha\bar{h}}{cN}\right) cw. \quad (10)$$

So far, we have assumed that each individual consumes all varieties. However, in the presence of income heterogeneity and finite marginal utility at zero consumption, some firms may find it profitable to deviate from the symmetric price by charging higher prices to higher income consumers while excluding lower income consumers. We now derive a sufficient condition under which there is no such incentive to unilaterally deviate from (9).

**Proposition 2** *Let  $\tilde{p}$  stand for the price charged by a firm which is unilaterally deviating from the symmetric price (9). A sufficient condition for (9) to be a price equilibrium, i.e., for such a unilateral deviation to be unprofitable, is that*

$$\frac{\theta \int_{h^l(\tilde{p})}^{\infty} h_H dG_H(h_H) + (1 - \theta) \int_{h^l(\tilde{p})}^{\infty} h_F dG_F(h_F)}{\theta \int_{h^l(\tilde{p})}^{\infty} dG_H(h_H) + (1 - \theta) \int_{h^l(\tilde{p})}^{\infty} dG_F(h_F)} \leq h^l(\tilde{p}) + \bar{h} + \frac{c}{\alpha} U(h^l(\tilde{p})), \quad \forall \tilde{p} > p, \quad (11)$$

where

$$h^l(\tilde{p}) \equiv \max \left\{ 0, \frac{Np}{\alpha w} \ln \left( \frac{\tilde{p}}{p} \right) \right\}. \quad (12)$$

is the labor efficiency of the marginal consumer.

**Proof.** See Appendix C. ■

We assume that the sufficient condition (11), which states that the average income of those who consume the variety must not rise too fast, holds throughout the paper. Note that it is never profitable to deviate from the symmetric price by charging lower prices ( $\tilde{p} < p$ ) because such a deviation does not affect the mass of consumers with positive demand, as can be seen

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<sup>10</sup>Using “0/1 preferences”, Foellmi *et al.* (2008) also obtain a similar product price when labor efficiency differs between countries but population sizes are the same. Note, however, that our product price depends both on income heterogeneity and on population shares. By contrast, the product price in Foellmi *et al.* (2008) includes trade costs. See Behrens *et al.* (2009) for how trade costs affect the product price in the CARA specification with heterogeneous firms.

from (12). In that case,  $p$ , as given by (9), is the unique profit-maximizing price. Note finally that FPE is compatible with income heterogeneity between and within countries because of the difference in labor efficiency. Hence, without loss of generality, we can restrict ourselves to the case in which FPE holds since our aim is to analyze the impact of trade on individual welfare in the presence of income heterogeneity, with less emphasis on the sources of this heterogeneity.

## 4 Homogeneous populations within each country

We first present the simple case in which all individuals within each country have the same labor efficiency. Without loss of generality, we assume that the labor efficiency in country  $H$  is higher than or equal to that in country  $F$ , i.e.,  $\bar{h}_H \geq \bar{h}_F$ .

### 4.1 Autarky

Assume that country  $r$  is in autarky (formally,  $\Omega_s = \emptyset$  and  $L_s = 0$ ). As shown by Behrens and Murata (2007), the price equilibrium without income heterogeneity is symmetric, which allows to alleviate notation by dropping the variety index  $i$ . Inserting (1) into (5), and letting  $q_{rs} = 0$ , the unique price equilibrium is given by:

$$p_r^a = \left(1 + \frac{\alpha \bar{h}_r}{cn_r^a}\right) cw_r^a, \quad (13)$$

where an  $a$ -superscript denotes autarky values. Note that (13) is a special case of the symmetric price equilibrium (10).

The symmetric price equilibrium implies that the budget constraint can then be rewritten as  $q_r^a = (w_r^a \bar{h}_r) / (n_r^a p_r^a)$ , which, when inserted into the labor market clearing condition (6), yields:

$$n_r^a = \frac{L_r \bar{h}_r}{f} \left(1 - \frac{cw_r^a}{p_r^a}\right). \quad (14)$$

Expressions (13) and (14) allow us to solve for the equilibrium mass of firms as follows:<sup>11</sup>

$$n_r^a = \bar{h}_r D(L_r) \quad \text{where} \quad D(L_r) \equiv \frac{\sqrt{4\alpha cf L_r + (\alpha f)^2} - \alpha f}{2cf} > 0. \quad (15)$$

It is readily verified that  $n_r^a$  is increasing in  $\bar{h}_r$  for any given value of  $L_r \bar{h}_r$ . Put differently, in autarky, a higher average labor efficiency  $\bar{h}_r$  maps into greater product diversity for any given aggregate labor supply  $L_r \bar{h}_r$ . The intuition is that an increase in  $\bar{h}_r$  makes demands less elastic, because consumers are richer and thus less price sensitive. As can be seen from (13), this raises markups, thus leading to entry and to the production of more varieties.

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<sup>11</sup>Note that the other root is negative and must, therefore, be ruled out.

## 4.2 Free trade

We now analyze the impact of globalization on welfare when populations are homogeneous within each country. To do so, we first restate the sufficient condition for the symmetric price equilibrium (11) and derive the equilibrium under free trade. As shown in Appendix C, a unilateral deviation is possibly profitable only when the firm can affect the marginal consumer. Since the density function has a point-mass at  $\bar{h}_r$  when populations are homogeneous within each country, the mass of individuals with positive demand changes at  $\bar{h}_F$  and  $\bar{h}_H$ . Because  $\bar{h}_F \leq \bar{h}_H$  by assumption, three cases may arise: (i)  $h^l(\tilde{p}) \in (0, \bar{h}_F)$ , where all consumers have positive demand; (ii)  $h^l(\tilde{p}) \in [\bar{h}_F, \bar{h}_H)$ , where only consumers in country  $H$  have positive demand; and (iii)  $h^l(\tilde{p}) \in [\bar{h}_H, \infty)$ , where no consumer has positive demand.

Obviously, there is no incentive for the firm to deviate from the symmetric price  $p$  to the prices corresponding to cases (i) and (iii). This is because the deviating firm cannot change the mass of consumers it faces in case (i), whereas in case (iii) it faces zero demand. In what follows, we thus focus on case (ii).<sup>12</sup> Because the demand functions are differentiable with respect to  $\tilde{p}$  when  $h^l(\tilde{p}) \in [\bar{h}_F, \bar{h}_H)$ , the sufficient condition for a symmetric price equilibrium given in Proposition 2 can be rewritten as:

$$\bar{h}_H \leq h^l(\tilde{p}) + \bar{h} + \frac{c}{\alpha} U(h^l(\tilde{p})) \quad \forall \tilde{p} \text{ such that } h^l(\tilde{p}) \in [\bar{h}_F, \bar{h}_H). \quad (16)$$

When condition (16) holds, which we previously assumed to be the case, Proposition 1 implies that the price equilibrium is symmetric and given by (10). Because prices and wages are equalized, all firms sell the same quantity  $Q = (L_H \bar{h}_H + L_F \bar{h}_F)(w/Np)$ . Labor market clearing then implies that  $n_H/n_F = (L_H \bar{h}_H)/(L_F \bar{h}_F)$ , which yields

$$n_r = \frac{L_r \bar{h}_r}{f} \left( 1 - \frac{cw}{p} \right), \quad (17)$$

Inserting (10) into (17), and doing the same with the analogous expressions for  $s \neq r$ , we obtain two equations with two unknowns  $n_H$  and  $n_F$  (recall that  $N \equiv n_H + n_F$ ). Solving for the equilibrium masses of firms, we readily obtain

$$n_H = \theta \bar{h}_H D(L) \quad \text{and} \quad n_F = (1 - \theta) \bar{h}_F D(L).$$

The equilibrium mass of firms in the global economy is then given by

$$N \equiv n_H + n_F = \bar{h} D(L). \quad (18)$$

Comparing expressions (14) and (17), we see that  $n_r < n_r^a$  if and only if the free trade price-wage ratio is smaller than the autarky price-wage ratio. We show that this is always the case, as in Krugman (1979) and Feenstra (2004). Interestingly, unlike in the existing literature without income heterogeneity between countries, we further show that product diversity in

<sup>12</sup>Note that case (ii) does not arise when  $\bar{h}_F = \bar{h}_H$  so that the price equilibrium is symmetric.

consumption may not expand for all individuals when switching from autarky to trade. The following proposition summarizes the results.

**Proposition 3** *Assume that the labor efficiency in country  $H$  is greater than or equal to that in country  $F$ , i.e.,  $\bar{h}_H \geq \bar{h}_F$ . When compared with autarky, we show that under free trade: (i) the mass of varieties consumed in country  $H$  decreases if and only if*

$$\bar{h}_H D(L_H) > \bar{h} D(L), \quad (19)$$

*whereas that in country  $F$  always increases; (ii) the mass of varieties produced in each country decreases; and (iii) the price-wage ratio falls in each country.*

**Proof.** Since by assumption  $\bar{h}_F \leq \bar{h} \leq \bar{h}_H$  and  $\max\{L_H, L_F\} < L$ , expressions (15) and (18) reveal that  $N > n_F^a$ , whereas  $N \gtrless n_H^a$  if and only if  $\bar{h}_H D(L_H) \gtrless \bar{h} D(L)$ , which establishes (i). Comparing (10) and (13) establishes (iii) because (15) and (18) imply  $\bar{h}_r/n_r^a > \bar{h}/N$  for  $r = H, F$ . By (14) and (17), this implies that  $n_r < n_r^a$  for  $r = H, F$ , thus proving (ii). ■

It is worth noting that variable elasticity and income heterogeneity between countries are crucial for our results. Baldwin and Forslid (2006) and Arkolakis *et al.* (2008) obtain a similar variety loss in CES models with firm heterogeneity. However, welfare implications of our variety loss are quite different from theirs. As we show in Section 5, welfare decreases for a subset of consumers in our model because, unlike in their CES models, the relative importance of variety versus quantity changes with income. On the contrary, Baldwin and Forslid (2006) and Arkolakis *et al.* (2008) show that welfare rises even when there is a variety loss.

Some comments are in order. First, one may ask whether there always exists  $\bar{h}_H$  satisfying both (16) and (19). To check this, note that the sufficient condition (16) is satisfied when

$$1 \leq \frac{\bar{h}_H}{\bar{h}_F} \leq \frac{2 - \theta}{1 - \theta} \equiv \Phi(\theta),$$

where we use the more stringent condition  $\bar{h}_H \leq \bar{h}_F + \bar{h} < h^l(\tilde{p}) + \bar{h} + (c/\alpha)U(h^l(\tilde{p}))$  for all  $\tilde{p}$  such that  $h^l(\tilde{p}) \in [\bar{h}_F, \bar{h}_H]$ . Expression (19), in turn, requires that

$$\frac{\bar{h}_H}{\bar{h}_F} > \frac{(1 - \theta)D(L)}{D(\theta L) - \theta D(L)} \equiv \Psi(\theta).$$

Noting that  $\lim_{\theta \rightarrow 0} \Phi(\theta) = 2$ ,  $\lim_{\theta \rightarrow 1} \Phi(\theta) = \infty$ ,  $\lim_{\theta \rightarrow 0} \Psi(\theta) = \infty$ ,  $\lim_{\theta \rightarrow 1} \Psi(\theta) = 2 + [\alpha + cD(L)]f/cL$ , and that  $\Phi$  is increasing whereas  $\Psi$  is decreasing in  $\theta \in [0, 1]$ ,  $\Phi$  and  $\Psi$  cross only once for  $\theta \in [0, 1]$ .<sup>13</sup> Based on these observations, the four possible cases are summarized in Figure 1.

**Insert Figure 1 about here.**

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<sup>13</sup>Note that  $\Psi$  is decreasing in  $\theta \in [0, 1]$  because  $\Psi$  is convex and  $\lim_{\theta \rightarrow 1} \Psi'(\theta) < 0$ .

Case (I) in Figure 1 shows that when  $\bar{h}_H/\bar{h}_F$  is sufficiently small, no firm wants to deviate, and hence, PPE and FPE hold. Furthermore, product diversity expands in both countries under free trade irrespective of the value of  $\theta$ . More interestingly, case (II) shows that there exists couples  $(\theta, \bar{h}_H/\bar{h}_F)$  such that no firm wants to deviate, and hence, PPE and FPE hold; whereas product diversity in consumption shrinks in the higher income country when switching from autarky to trade. This may make consumers in the higher income country worse off, depending on the relative importance of product diversity and pro-competitive effects. In cases (III) and (IV), when  $\bar{h}_H/\bar{h}_F$  is large enough, the sufficient condition for no deviation is not satisfied and hence PPE and FPE may not hold. Hence, the results on whether product diversity expands or not should be interpreted cautiously in these cases.

Second, Proposition 3 illustrates exit of firms due to the pro-competitive effects of international trade. As can be seen from the equilibrium price-wage ratios

$$\frac{p_r^a}{w_r^a} = c + \frac{\alpha}{D(L_r)} \quad \text{and} \quad \frac{p}{w} = c + \frac{\alpha}{D(L)}, \quad (20)$$

the equilibrium markups in both countries decrease under free trade, thus driving some firms out of each national market.<sup>14</sup> Labor market clearing then implies that firm-level and total production expands, as labor is reallocated from the fixed requirements of closing firms to the marginal requirements of surviving firms. Contrary to the growing literature on firm heterogeneity in international trade (e.g., Melitz, 2003), where the price-cost margin is usually constant because of the CES specification, our model captures the ‘old idea’ that international trade reduces markups and hence triggers exit of firms even without firm heterogeneity.<sup>15</sup>

Last, one can readily verified that

$$\frac{\partial n_r}{\partial L_r} > 0, \quad \frac{\partial n_s}{\partial L_r} < 0, \quad \frac{\partial n_r}{\partial \bar{h}_r} > 0 \quad \text{and} \quad \frac{\partial n_s}{\partial \bar{h}_r} = 0 \quad \text{for} \quad r \neq s.$$

Interestingly, an increase in population in country  $r$  reduces the mass of firms in country  $s$ , whereas an increase in average labor efficiency has no such impact. This is because there are both direct and indirect effects, as can be seen from (17). First, increases in population and average labor efficiency directly raise the domestic aggregate labor supply, thus increasing the mass of domestic firms. Second, an increase in population in country  $r$  has a negative effect on the equilibrium markups (20) and, therefore, reduces indirectly the equilibrium mass of firms in

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<sup>14</sup>In Lawrence and Spiller (1983, Proposition 7), trade leads to a redistribution of firms between the two countries while the total mass of firms remains unchanged. This result is driven by changes in relative factor prices and, as pointed out by the authors, need not hold under variable markups. Furthermore, they show in Proposition 5 that the price of the monopolistically competitive good falls in one country and rises in the other due to changes in relative factor prices. Yet, the markups remain constant because of the CES specification.

<sup>15</sup>One notable exception is Melitz and Ottaviano (2008) who recently proposed a model that explains trade-induced exit by combining pro-competitive effects and firm heterogeneity in a monopolistic competition framework. However, due to their quasi-linear specification, there is no point in introducing income heterogeneity in their model as higher income consumers would spend their additional income only on the numeraire good.

both countries, whereas an increase in average labor efficiency has no impact on the equilibrium markups.

### 4.3 Welfare decomposition and gains from trade

We analyze gains from trade by decomposing welfare changes into those due to product diversity and those due to pro-competitive effects. Since the price equilibrium is symmetric under both autarky and free trade, we have  $q^a = (w_r^a \bar{h}_r)/(n_r^a p_r^a)$  and  $q = (w \bar{h}_r)/(Np)$ . The utility difference between free trade and autarky in country  $r = H, F$  can then be expressed as follows:

$$\Delta U_r(\bar{h}_r) \equiv U_r(\bar{h}_r) - U_r^a(\bar{h}_r) = N \left( 1 - e^{-\frac{\alpha w \bar{h}_r}{Np}} \right) - n_r^a \left( 1 - e^{-\frac{\alpha w_r^a \bar{h}_r}{n_r^a p_r^a}} \right).$$

Adding and subtracting  $n_r^a e^{-\alpha w \bar{h}_r/(n_r^a p)}$  and rearranging, we obtain the following decomposition:

$$\Delta U_r(\bar{h}_r) \equiv \underbrace{N \left( 1 - e^{-\frac{\alpha w \bar{h}_r}{Np}} \right) - n_r^a \left( 1 - e^{-\frac{\alpha w \bar{h}_r}{n_r^a p}} \right)}_{\text{Product diversity}} + \underbrace{n_r^a \left( e^{-\frac{\alpha w_r^a \bar{h}_r}{n_r^a p_r^a}} - e^{-\frac{\alpha w \bar{h}_r}{n_r^a p}} \right)}_{\text{Pro-competitive effects}}, \quad (21)$$

which isolates the two channels, namely product diversity and pro-competitive effects, through which gains from trade materialize. The former captures welfare changes through product diversity given the wage-price ratio under free trade  $w/p$ , whereas the latter captures welfare changes through the wage-price ratio given product diversity under autarky  $n_r^a$ .

Using the results of Proposition 3 and the welfare decomposition (21), we first consider the benchmark case in which populations are homogeneous even between countries. Noting that expression (19) never holds when  $\bar{h}_H = \bar{h}_F$ , we can show the following proposition.

**Proposition 4** *Assume that the two countries have the same average labor efficiency, i.e.,  $\bar{h}_H = \bar{h}_F = \bar{h}$ . Then, free trade raises welfare through greater product diversity in consumption and through lower price-wage ratios.*

**Proof.** Proposition 3 shows that when  $\bar{h}_H = \bar{h}_F = \bar{h}$ , trade always expands product diversity in consumption, which raises welfare via ‘love-of-variety’ as follows. Given the price-wage ratio under free trade, we have  $U_r = N[1 - e^{-\alpha w \bar{h}/(Np)}]$  and  $\partial U_r/\partial N = 1 - e^{-\alpha w \bar{h}/(Np)}[1 + \alpha w \bar{h}/(Np)] > 0$  for all  $N$  and  $r = H, F$ . To obtain the last inequality, let  $z \equiv \alpha w \bar{h}/(Np)$  and  $\xi(z) \equiv 1 - e^{-z}(1 + z)$ . Clearly,  $\xi(0) = 0$  and  $\xi'(z) > 0$  for all  $z > 0$ , which shows that for any given price-wage ratio under free trade, utility increases in the mass of varieties consumed. Hence, the first term in (21) is positive. Similarly, by Proposition 3, we know that for any given mass of firms under autarky, the price-wage ratio falls under free trade, thus implying that the second term in (21) is also positive. ■

On the contrary, the mass of varieties consumed in country  $H$  may decrease when  $\bar{h}_H > \bar{h}_F$ , as can be seen from Proposition 3. More specifically, when  $\theta$  and  $\bar{h}_H/\bar{h}_F$  belong to (II) in

Figure 1, the first term in (21) is no longer positive. When this occurs, there may be losses from trade in the higher income country despite a fall in the price-wage ratios. In what follows, we explore this possibility by analyzing a more general case in which populations are heterogeneous both between and within countries.

## 5 Heterogeneous populations between and within countries

So far, we have shown that whenever there is a variety loss in the presence of income heterogeneity between countries, it occurs in the higher income country. We now analyze *who in the higher income country* may lose from trade by exploring gains from trade at the individual level.

### 5.1 Welfare decomposition and gains from trade

Unlike in the previous section where all individuals in a country are affected in the same way by trade, income heterogeneity within a country matters when assessing who gains and who loses from trade. This is because trade may have opposite welfare effects on consumers in the higher income country through variety and quantity, and their relative importance changes with income. As in Section 4.3, welfare changes of an individual with labor efficiency  $h_r$  are measured by  $\Delta U_r(h_r)$ , which can now be decomposed as follows:

$$\Delta U_r(h_r) \equiv \underbrace{N \left( 1 - e^{-\frac{\alpha w h_r}{N p}} \right) - n_r^a \left( 1 - e^{-\frac{\alpha w h_r}{n_r^a p}} \right)}_{\text{Product diversity}} + \underbrace{n_r^a \left( e^{-\frac{\alpha w_r^a h_r}{n_r^a p_r^a}} - e^{-\frac{\alpha w h_r}{n_r^a p}} \right)}_{\text{Pro-competitive effects}}. \quad (22)$$

This expression is analogous to (21) except that it depends on the individual labor efficiency  $h_r$  instead of on the average  $\bar{h}_r$ . Since in our model demand functions are linear in expenditure, the price equilibrium and the equilibrium mass of firms depend only on the average labor efficiency. Hence, Proposition 3 carries over to the case of income heterogeneity within each country. Using (22), we can prove the following proposition.

**Proposition 5** *Assume that country  $H$  has a higher average labor efficiency than country  $F$ , i.e.,  $\bar{h}_H > \bar{h} > \bar{h}_F$ . Then, when (19) holds, there exists a unique threshold  $h_H^{\text{loss}}$  in country  $H$  such that  $\Delta U_H(h_H) \geq 0$  for  $h_H \leq h_H^{\text{loss}}$ . Otherwise, free trade raises the welfare of all consumers in country  $H$ . In country  $F$ , free trade always raises the welfare of all consumers.*

**Proof.** See Appendix D. ■

Proposition 5 shows that it is the richer consumers in the higher income country who may lose from trade, because the relative importance of variety versus quantity increases with income. The intuition is that since utility is bounded for each variety in our framework, the richer

consumers benefit only little from increased quantity due to a fall in the price-wage ratios, whereas a decrease in product diversity hurts them. On the contrary, lower income consumers care less about variety but more about quantity, and they gain from trade even when facing less product diversity because the lower price-wage ratios allow them to consume more of each variety. Note that the losses from trade due to income heterogeneity are reminiscent of those in Epifani and Gancia (2009), who show that markup heterogeneity across sectors causes welfare losses under restricted entry despite the decline in the average markup. However, welfare always increases when entry is free in their framework. In our model, losses from trade may exist even when entry is unrestricted, but only for a subset of consumers because of income heterogeneity.

## 5.2 Numerical illustration

How many individuals in the higher income country may lose from trade? The answer depends on the distribution functions  $G_H$  and  $G_F$ , which we have not specified until now. To measure the share of individuals who lose from trade, we focus on two-parameter distributions, in particular Gamma and Lognormal, because these distributions provide reasonably good approximations of income distributions in many countries.

We illustrate the quantitative effects of our model for U.S. consumers. To this end, we use data on real GDP per capita and population, as well as parameter estimates for the U.S. income distribution. Our sample consists of 188 countries in 1997 obtained from the Penn World Table Version 6.2, from which we exclude Angola and Libya as no data on real GDP per capita is available. The estimates of shape and scale parameters for the U.S. household income distribution in 1997 are taken from Bandourian *et al.* (2002). We are not aware of any recent estimates of these parameters for the U.S. personal income distribution and therefore make the admittedly strong assumption that the personal and household income distributions have the same shape. We then approximate the scale parameters of the other countries by assuming that they are proportional to those of the U.S., with proportionality coefficient given by real GDP per capita relative to the U.S. The shape parameters are assumed to be the same as those of the U.S. While the latter assumption is solely motivated by the lack of data, it is not very restrictive since the shape parameters of the trading partners matter only for checking the sufficient condition (11). As it is not generally possible to check the no-deviation condition analytically, we verify it numerically for the two income distributions to see whether they are compatible with a symmetric price equilibrium.<sup>16</sup> We then check whether product diversity in consumption decreases, by evaluating condition (19) using the equilibrium values. If there is a variety loss, we solve for the labor efficiency of the marginal consumer by equating (22) to zero, which allows us to compute the mass of losers whose income exceeds the computed threshold.

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<sup>16</sup>To do so, we evaluate (11) for values of  $h^l(\tilde{p})$  ranging from 10 to 100000 with step 10. Results are robust to different ranges and step sizes.



**Insert Figures 2 and 3 about here.**

Figures 2 and 3 depict the relationship between the share of the U.S. population who lose from trade and real GDP per capita of the trading partners for Gamma and Lognormal distributions, respectively.<sup>17</sup> Note that U.S. intra-industry trade with countries of similar GDP per capita makes all individuals better off because it reduces the price-wage ratios and expands the range of varieties consumed in both countries, as shown in Propositions 3 and 4. However, U.S. trade with countries having lower GDP per capita may adversely affect up to 11% of the U.S. population. The reason is that although the price-wage ratios decrease, such trade reduces product diversity in consumption. Note that when the trading partners' GDP per capita is sufficiently small, condition (11) is violated, thus indicating that our results need to be interpreted cautiously because PPE and FPE may not hold.

**Insert Tables 1 and 2 about here.**

As can be seen from Tables 1 and 2, for both income distributions, 22 out of the 28 OECD trading partners in 1997 lead to 0% of losers. For the remaining 6 OECD trading partners (Czech Republic, Greece, Hungary, Poland, Mexico, and Turkey), the percentage of losers ranges from about 0% to a maximum of almost 6% for Turkey. In other words, intra-industry trade between the OECD countries is beneficial to a broad mass of consumers. Tables 1 and 2 also show that U.S. trade with countries like China and India may yield a non-negligible share of losers in the U.S. (from about 12% to about 20%, depending on the distribution functions).

In this numerical illustration, we have so far focused mainly on the share of losers in the U.S. by assuming that the U.S. actually trades with each trading partner. We can assess whether the U.S. as a whole is likely to agree on free trade with each potential trading partner. Needless to say, this requires an assumption on a relevant political process. Although such an analysis is beyond the scope of this paper, Tables 1 and 2 show that the share of potential losers is not overwhelming in all cases, thus suggesting that U.S. intra-industry trade even with highly dissimilar countries need not require protection.<sup>18</sup>

**Insert Figures 4 and 5 and Table 3 about here.**

Finally, we illustrate the decomposition of welfare changes at the individual level based on (22). To do this, we restrict ourselves to the Gamma distribution and focus on Canada and Mexico as U.S. trading partners. As can be seen from Table 1, there are no losers in the U.S. from trade with Canada. In the case of Mexico, however, the percentage of losers

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<sup>17</sup>In what follows, we choose the following parameter values:  $\alpha = 0.3$ ;  $c = 0.1$ ; and  $F = 0.1$ .

<sup>18</sup>This can be seen, for example, as follows. Recall our argument in the Introduction that compensation mechanisms are unlikely to be operational, and consider a simple political process based on majority voting. Let  $\hat{h}_H$  stand for the median of the distribution  $G_H$ . Then, comparing  $h_H^{\text{loss}}$  and  $\hat{h}_H$ , we see that free trade is the social outcome if and only if  $\hat{h}_H < h_H^{\text{loss}}$ . Clearly, this is always the case in Tables 1 and 2.

in the U.S. is 1.09 with the threshold  $h_H^{\text{loss}} = 173687$ . Figures 4 and 5 illustrate how product diversity and pro-competitive effects due to trade with Canada and Mexico contribute to welfare changes for U.S. consumers depending on their income. As expected, the relative importance of product diversity increases in income in both cases. This can also be seen from Table 3, which summarizes the welfare changes due to trade with Canada for U.S. consumers at selected income percentiles.

## 6 Concluding remarks

Globalization is widely believed to yield gains from trade at the aggregate level, yet produces winners and losers at the individual level. In this paper, we have analyzed the impact of globalization on individual gains from trade in a general equilibrium model of monopolistic competition featuring income heterogeneity between and within countries. We have shown that, although trade always reduces markups in both countries, its impact on product diversity in consumption depends on their relative position in the world income distribution. Indeed, the range of varieties consumed in the lower income country always expands, while that in the higher income country may shrink. When the latter occurs, it is the richer consumers in the higher income country who may lose from trade because the relative importance of variety versus quantity increases with income. We have illustrated the quantitative effects of the model using data on GDP per capita and population for 186 countries, as well as parameter estimates for domestic income distributions. It turns out that U.S. trade with countries of similar GDP per capita makes all agents in both countries better off, whereas trade with countries having lower GDP per capita may adversely affect up to 11% of the U.S. population.

In order to focus entirely on how globalization affects individual welfare through product diversity and pro-competitive effects, we have developed a highly stylized model. The following two points should therefore be kept in mind when interpreting our results. First, to focus on income heterogeneity, our analysis abstracts from firm heterogeneity and trade costs (see Behrens *et al.*, 2009, for an application of our CARA specification to firm heterogeneity and trade costs). Introducing all these elements into a single framework appears to be a promising extension in order to get a more complete picture of the impact of globalization on individual gains from trade.

Second, our analysis assumes that there is a single production factor, which rules out the role of relative factor prices in determining individual welfare. By contrast, when there is more than one factor, for instance, skilled and unskilled workers, factor proportions theory generally predicts that skilled workers in a skill abundant country will gain from trade, whereas the unskilled in that country will lose from trade. Our results thus suggest that such Stolper-Samuelson effects may get weakened or even reversed when product diversity, pro-competitive effects, and income heterogeneity are taken into account. Ultimately, trade may not generate

as much inequality in individual welfare than predicted by factor proportions theory.

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## Appendix A: Derivation of the demand functions

Letting  $\lambda$  stand for the Lagrange multiplier, the first-order conditions for an interior solution are given by:

$$\alpha e^{-\alpha q_{rr}(i, h_r)} = \lambda p_r(i), \quad \forall i \in \Omega_r \quad (23)$$

$$\alpha e^{-\alpha q_{sr}(j, h_r)} = \lambda p_s(j), \quad \forall j \in \Omega_s \quad (24)$$

and the budget constraint

$$\int_{\Omega_r} p_r(k) q_{rr}(k, h_r) dk + \int_{\Omega_s} p_s(k) q_{sr}(k, h_r) dk = E_r(h_r). \quad (25)$$

Taking the ratio of (23) with respect to  $i$  and  $j$ , we obtain

$$q_{rr}(i, h_r) = q_{rr}(j, h_r) + \frac{1}{\alpha} \ln \left[ \frac{p_r(j)}{p_r(i)} \right] \quad \forall i, j \in \Omega_r.$$

Multiplying this expression by  $p_r(j)$  and integrating with respect to  $j \in \Omega_r$  we obtain

$$q_{rr}(i, h_r) \int_{\Omega_r} p_r(j) dj = \int_{\Omega_r} p_r(j) q_{rr}(j, h_r) dj + \frac{1}{\alpha} \int_{\Omega_r} \ln \left[ \frac{p_r(j)}{p_r(i)} \right] p_r(j) dj. \quad (26)$$

Analogously, taking the ratio of (23) and (24) with respect to  $i$  and  $j$ , we get:

$$q_{rr}(i, h_r) = q_{sr}(j, h_r) + \frac{1}{\alpha} \ln \left[ \frac{p_s(j)}{p_r(i)} \right] \quad \forall i \in \Omega_r, \forall j \in \Omega_s.$$

Multiplying this expression by  $p_s(j)$  and integrating with respect to  $j \in \Omega_s$  we obtain

$$q_{rr}(i, h_r) \int_{\Omega_s} p_s(j) dj = \int_{\Omega_s} p_s(j) q_{sr}(j, h_r) dj + \frac{1}{\alpha} \int_{\Omega_s} \ln \left[ \frac{p_s(j)}{p_r(i)} \right] p_s(j) dj. \quad (27)$$

Summing expressions (26) and (27), and using the budget constraint (25), we finally obtain the demands (1). The derivation of the demands (2) is analogous.

## Appendix B: Proof of Proposition 1

Using (1), (2) and the definition of output per firm, it is readily verified that

$$Q_H(i) - Q_F(j) = -\frac{L}{\alpha} \ln \left[ \frac{p_H(i)}{p_F(j)} \right]. \quad (28)$$

Because each individual is assumed to consume all varieties, the first-order conditions (5) must hold for all firms in countries  $H$  and  $F$ . Using expression (28), one can check that

$$\frac{\partial \Pi_H(i)}{\partial p_H(i)} - \frac{\partial \Pi_F(j)}{\partial p_F(j)} = 0 \quad \iff \quad c \left[ \frac{w_H}{p_H(i)} - \frac{w_F}{p_F(j)} \right] = \ln \left[ \frac{p_H(i)}{p_F(j)} \right]. \quad (29)$$

Furthermore, from expression (4) the zero profit condition requires that

$$\frac{\Pi_r(i)}{w_r} = \left[ \frac{p_r(i)}{w_r} - c \right] Q_r(i) - f = 0 \quad \text{for } r = H, F.$$

Assume that there exists  $i \in \Omega_H$  and  $j \in \Omega_F$  such that  $p_H(i) > p_F(j)$ . Then (29) implies that  $w_H/p_H(i) > w_F/p_F(j)$  or, equivalently, that  $p_H(i)/w_H < p_F(j)/w_F$ , whereas (28) implies that  $Q_H(i) < Q_F(j)$ . Hence,  $\Pi_H(i)/w_H < \Pi_F(j)/w_F$ , which is incompatible with the zero profit condition at least in one country. We thus conclude that  $p_H(i) = p_F(j)$  must hold for all  $i \in \Omega_H$  and  $j \in \Omega_F$ , which shows that product prices are equalized. Expression (29) then shows that  $w_H = w_F$ , i.e., factor prices are equalized whenever product prices are equalized. Finally, setting  $p_r(i) = p_s(j) = p$  and  $w_r = w_s = w$  in (5) yields expression (9).

## Appendix C: Proof of Proposition 2

We derive a sufficient condition for the symmetric price  $p$ , as given by (9), to be a price equilibrium in the presence of income heterogeneity and finite marginal utility at zero consumption.<sup>19</sup> To alleviate notation, we suppress subscripts whenever there is no possible confusion. Taking into account the fact that demands need not be strictly positive, aggregate demand is given by  $Q_r(i) = L_r \int_0^\infty \max\{0, q_{rr}(i, h_r)\} dG_r(h_r) + L_s \int_0^\infty \max\{0, q_{rs}(i, h_s)\} dG_s(h_s)$ .

We now examine under which conditions firms have no incentive to unilaterally deviate from the symmetric price (9) even when individuals are allowed not to consume all varieties. Assume that one firm charges the price  $\tilde{p}$ , whereas all the other firms charge the price  $p$  given by (9). Since the deviating firm is negligible to the market, wages are unaffected and remain equalized between the two countries. The labor efficiency of the marginal consumer must satisfy  $q_{rr}(\tilde{p}, h^l(\tilde{p})) = q_{rs}(\tilde{p}, h^l(\tilde{p})) = 0$ , which yields (12). Letting  $\tilde{h} \equiv h^l(\tilde{p})$ , we can rewrite the demand function of the deviating firm as follows:

$$Q_r(\tilde{p}) = L_r \int_{\tilde{h}}^\infty q_{rr}(i, h_r) dG_r(h_r) + L_s \int_{\tilde{h}}^\infty q_{rs}(i, h_s) dG_s(h_s). \quad (30)$$

Differentiating (30) with respect to  $\tilde{p}$  and applying the Leibniz integral rule, we get:

$$Q'_r(\tilde{p}) = L_r \int_{\tilde{h}}^\infty \frac{\partial q_{rr}(\tilde{p}, h_r)}{\partial \tilde{p}} dG_r(h_r) + L_s \int_{\tilde{h}}^\infty \frac{\partial q_{rs}(\tilde{p}, h_s)}{\partial \tilde{p}} dG_s(h_s), \quad (31)$$

where we have used the properties  $q_{rr}(\tilde{p}, \tilde{h}) = q_{rs}(\tilde{p}, \tilde{h}) = 0$ . The operating profit of the deviating firm is given by  $\pi_r(\tilde{p}) = (\tilde{p} - cw)Q_r(\tilde{p})$ . Imposing symmetry on prices, on quantities, and on their derivatives, we then have

$$q_{rr}(\tilde{p}, h_r) = \frac{wh_r}{Np} - \frac{1}{\alpha} \ln\left(\frac{\tilde{p}}{p}\right), \quad \frac{\partial q_{rr}(\tilde{p}, h_r)}{\partial \tilde{p}} = -\frac{1}{\alpha\tilde{p}} \quad (32)$$

$$q_{rs}(\tilde{p}, h_s) = \frac{wh_s}{Np} - \frac{1}{\alpha} \ln\left(\frac{\tilde{p}}{p}\right), \quad \frac{\partial q_{rs}(\tilde{p}, h_s)}{\partial \tilde{p}} = -\frac{1}{\alpha\tilde{p}}. \quad (33)$$

<sup>19</sup>See Saint-Paul (2006) for a similar analysis of this problem in the context of a closed economy.

Plugging (32) and (33) into (30) and (31), we get

$$\begin{aligned} Q_r(\tilde{p}) &= \frac{w}{Np} \left[ L_r \int_{\tilde{h}}^{\infty} h_r dG_r(h_r) + L_s \int_{\tilde{h}}^{\infty} h_s dG_s(h_s) \right] \\ &\quad - \frac{1}{\alpha} \ln \left( \frac{\tilde{p}}{p} \right) \left[ L_r \int_{\tilde{h}}^{\infty} dG_r(h_r) + L_s \int_{\tilde{h}}^{\infty} dG_s(h_s) \right] \\ Q'_r(\tilde{p}) &= -\frac{1}{\alpha \tilde{p}} \left[ L_r \int_{\tilde{h}}^{\infty} dG_r(h_r) + L_s \int_{\tilde{h}}^{\infty} dG_s(h_s) \right]. \end{aligned}$$

We now classify all possible deviations from symmetry into two cases: (i)  $\tilde{p} < p$  and (ii)  $\tilde{p} > p$ .

**Case (i):**  $\tilde{p} < p$

From expression (12), we obtain  $\tilde{h} = 0$ . Hence, a unilateral deviation with a lower price is not profitable since for any  $\tilde{p} < p$  we have

$$\begin{aligned} \frac{\partial \pi_r(\tilde{p})}{\partial \tilde{p}} &= L \left[ \frac{w\bar{h}}{Np} - \frac{1}{\alpha} \ln \left( \frac{\tilde{p}}{p} \right) - \frac{\tilde{p} - cw}{\alpha \tilde{p}} \right] \\ &> L \left[ \frac{w\bar{h}}{Np} - \frac{1}{\alpha} \ln \left( \frac{\tilde{p}}{p} \right) - \frac{p - cw}{\alpha p} \right] = -\frac{1}{\alpha} \ln \left( \frac{\tilde{p}}{p} \right) > 0, \end{aligned}$$

where we have used the definition of  $p$  in the last step.

**Case (ii):**  $\tilde{p} > p$

Given the result in case (i), a sufficient condition for (9) to be a symmetric price equilibrium is that  $\partial \pi_r(\tilde{p})/\partial \tilde{p} \leq 0$  for all  $\tilde{p} > p$ . This condition can be expressed as follows:

$$\begin{aligned} &\frac{w}{Np} \left[ L_r \int_{\tilde{h}}^{\infty} h_r dG_r(h_r) + L_s \int_{\tilde{h}}^{\infty} h_s dG_s(h_s) \right] \\ &\leq \left[ \frac{1}{\alpha} \ln \left( \frac{\tilde{p}}{p} \right) + \frac{\tilde{p} - cw}{\alpha \tilde{p}} \right] \left[ L_r \int_{\tilde{h}}^{\infty} dG_r(h_r) + L_s \int_{\tilde{h}}^{\infty} dG_s(h_s) \right] \end{aligned}$$

for all  $\tilde{p} > p$ . Using (12), and because  $\tilde{p} > p$ , the condition can be rewritten as

$$L_r \int_{\tilde{h}}^{\infty} h_r dG_r(h_r) + L_s \int_{\tilde{h}}^{\infty} h_s dG_s(h_s) \leq \left[ \tilde{h} + \frac{Np}{\alpha w} \left( 1 - \frac{cw}{\tilde{p}} \right) \right] \left[ L_r \int_{\tilde{h}}^{\infty} dG_r(h_r) + L_s \int_{\tilde{h}}^{\infty} dG_s(h_s) \right]$$

for all  $\tilde{p} > p$ . Since  $p/\tilde{p} = e^{-\alpha w \tilde{h}/(Np)}$  by (12) we obtain

$$\frac{\theta \int_{\tilde{h}}^{\infty} h_r dG_r(h_r) + (1 - \theta) \int_{\tilde{h}}^{\infty} h_s dG_s(h_s)}{\theta \int_{\tilde{h}}^{\infty} dG_r(h_r) + (1 - \theta) \int_{\tilde{h}}^{\infty} dG_s(h_s)} \leq \tilde{h} + \frac{Np}{\alpha w} - \frac{cN}{\alpha} e^{-\frac{\alpha w \tilde{h}}{Np}},$$

where we have used the definition of the population share  $\theta$ . Using  $p = [c + (\alpha \bar{h}/N)]w$ ,  $q(p, \tilde{h}) = w\tilde{h}/(Np)$  and the expression of the utility function, we finally obtain (11).



## Appendix D: Proof of Proposition 5

The first part of Proposition 5 can be established as follows. When condition (19) holds, free trade reduces the mass of varieties consumed in country  $H$ , while the price-wage ratio decreases. Hence, two opposing effects are at work and the overall outcome is a priori ambiguous. In general, it will depend on the value of  $h_H$ . To see this, we proceed as follows. First, evaluating (22) at the price equilibrium and at the equilibrium mass of firms, and differentiating the resulting expression with respect to  $h_H$ , it is verified that

$$\frac{\partial(\Delta U_H(h_H))}{\partial h_H} = \frac{\alpha N}{\alpha \bar{h} + cN} \exp\left(-\frac{\alpha h_H}{\alpha \bar{h} + cN}\right) - \frac{\alpha n_H^a}{\alpha \bar{h}_H + c n_H^a} \exp\left(-\frac{\alpha h_H}{\alpha \bar{h}_H + c n_H^a}\right) \quad (34)$$

and that

$$\frac{\partial(\Delta U_H(h_H))}{\partial h_H} \Big|_{h_H=0} > 0 \iff \frac{N}{n_H^a} = \frac{[\alpha + cD(L)] \bar{h}}{[\alpha + cD(L_H)] \bar{h}_H} > \frac{\bar{h}}{\bar{h}_H}, \quad (35)$$

which always holds. This establishes that  $\Delta U_H$  is positively sloped at  $h_H = 0$ . Second, note that the derivative (34) has a unique root, which is given by

$$h_H^{\text{ext}} = \frac{(\alpha \bar{h} + cN)(\alpha \bar{h}_H + c n_H^a)}{\alpha[\alpha(\bar{h}_H - \bar{h}) + c(n_H^a - N)]} \ln\left(\frac{\alpha \bar{h}_H N + c n_H^a N}{\alpha \bar{h} n_H^a + c n_H^a N}\right), \quad (36)$$

such that  $h_H^{\text{ext}} > 0$  if and only if  $\alpha(\bar{h}_H - \bar{h}) + c(n_H^a - N) > 0$ . Third, since

$$\text{sgn} \left[ \frac{\partial^2(\Delta U_H(h_H))}{\partial h_H^2} \Big|_{h_H=h_H^{\text{ext}}} \right] = \text{sgn} \left\{ -[\alpha(\bar{h}_H - \bar{h}) + c(n_H^a - N)] \right\}, \quad (37)$$

the associated extremum is: (i) a local maximum when  $h_H^{\text{ext}} > 0$ ; and (ii) a local minimum when  $h_H^{\text{ext}} < 0$ . We now analyze these two cases.

### Case (i): $h_H^{\text{ext}} > 0$

Two sub-cases may emerge. First, when (19) holds, we have  $N < n_H^a$ , which then implies that  $\lim_{h_H \rightarrow \infty} \Delta U_H(h_H) = N - n_H^a < 0$ . In this case, there exists a unique threshold  $h_H^{\text{loss}}$  such that  $\Delta U_H(h_H) \gtrless 0$  for  $h_H \gtrless h_H^{\text{loss}}$ , since (35) and  $\Delta U_H(0) = 0$  hold and  $\Delta U_H$  is continuous in  $h_H$ . Second, when (19) does not hold, we have  $N > n_H^a$ . In this case, free trade raises the welfare of all consumers in country  $H$  through increased product diversity ( $N > n_H^a$ ) and lower price-wage ratios ( $p/w < p_H^a/w_H^a$ ).

### Case (ii): $h_H^{\text{ext}} < 0$

Since (35) and  $\Delta U_H(0) = 0$  hold and  $\Delta U_H$  is continuous and strictly increasing for all  $h_H \geq 0$ , all individuals in country  $H$  gain from trade.

The second part of Proposition 5 directly result from the expansion of product diversity in consumption ( $N > n_F^a$ ) and the decrease in the price-wage ratios ( $p/w < p_F^a/w_F^a$ ).

Figure 1: Product diversity in country  $H$  and no deviation condition when populations are homogeneous within each country

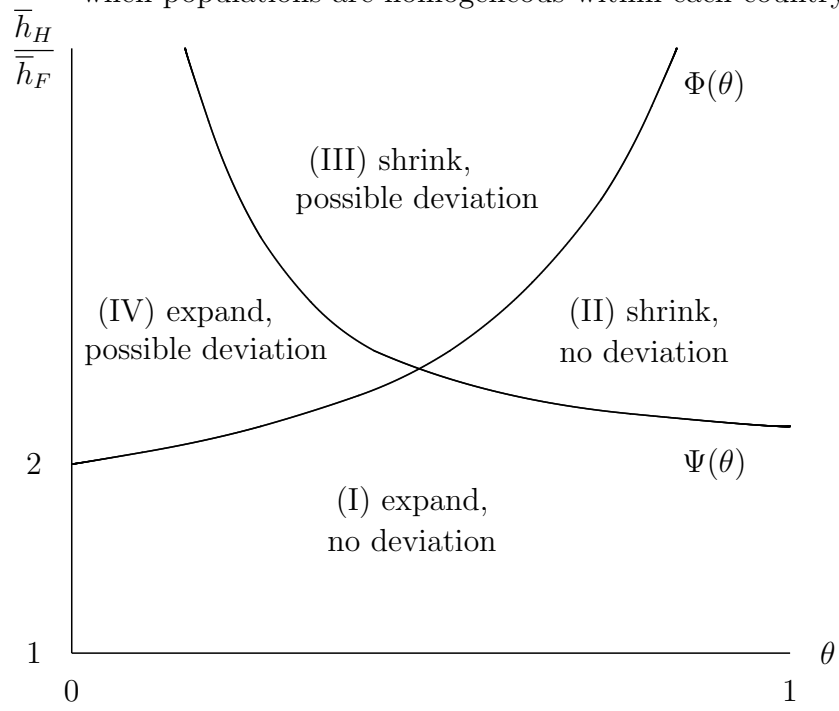


Figure 2: Gamma distribution

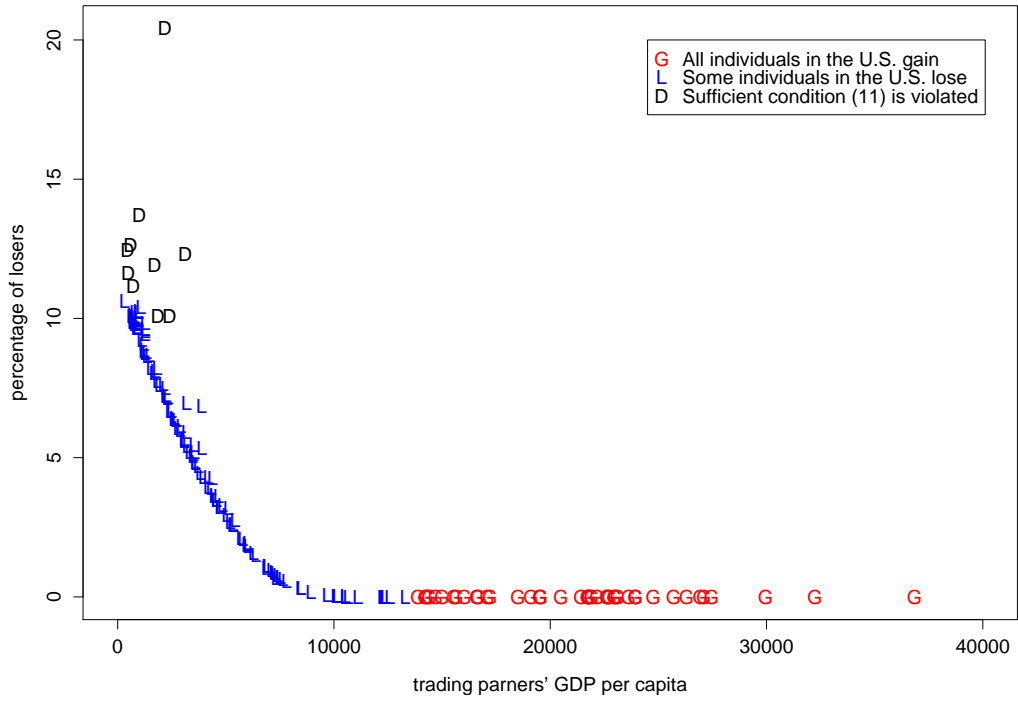


Figure 3: Lognormal distribution

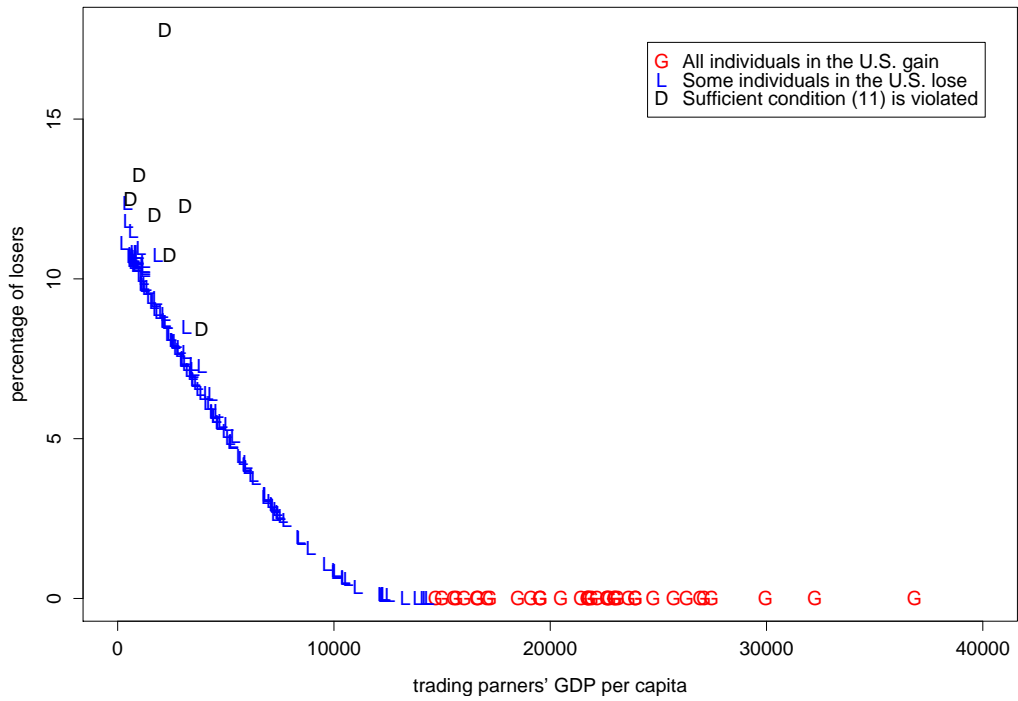


Figure 4: Decomposition of welfare changes due to trade with Canada (Gamma distribution)

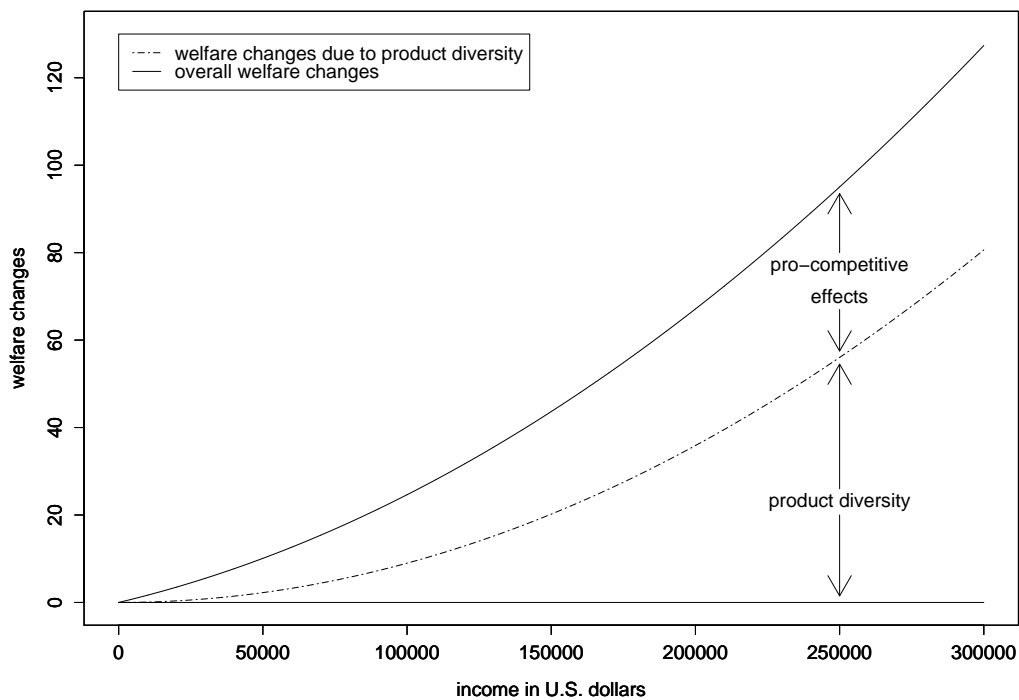


Figure 5: Decomposition of welfare changes due to trade with Mexico (Gamma distribution)

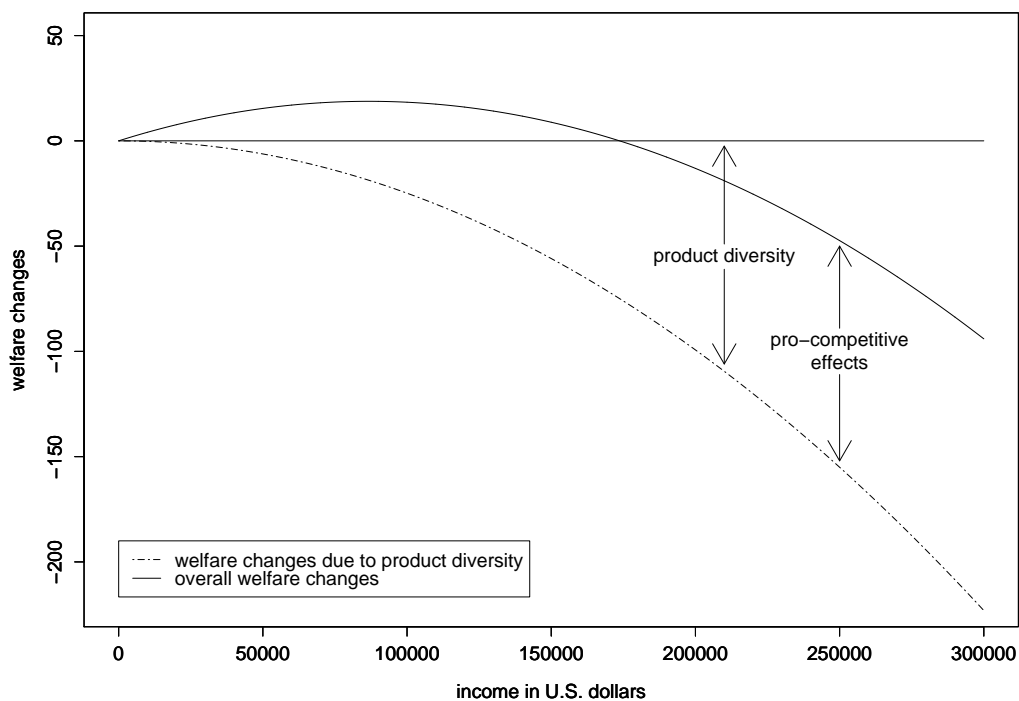


Table 1: Percentage of losers in the U.S. (Gamma distribution)

Percentage	Country codes (as from the Penn World Table Version 6.2)
= 0	AUS*, AUT*, BHS, BHR, BRB, BEL*, BMU, BRN, CAN*, CYP, DNK*, FIN*, FRA*, GER*, HKG, ISL*, IRL*, ISR, ITA*, JPN*, KOR*, KWT, LUX*, MAC, MLT, NLD*, ANT, NZL*, NOR*, PRT*, PRI, QAT, SAU, SGP, SVN, ESP*, SWE*, CHE*, TWN, ARE, GBR*
(0, 1]	OMN, KNA, CZE*, ATG, MUS, GRC*, ARG, TTO, CHL, URY, MYS, SYC, PLW, HUN*, EST, SVK, GAB, HRV, LTU, RUS, BLR, ZAF, POL*, CRI, LVA, DMA, PAN
(1, 2]	BRA, MEX*, VEN, THA, LBN, VCT, SWZ, BWA, LCA, TUN, COL
(2, 3]	BGR, BLZ, DOM, TKM, KAZ, PRY, TUR*, CUB
(3, 4]	IRN, NAM, GRD, ROM, FJI, MKD, JAM, DZA, SLV, ECU, SUR
(4, 5]	UKR, PER, JOR, MDV, PNG, FSM, CPV
(5, 6]	GEO, GTM, DJI, LKA, EGY, GUY, MAR, TON, VUT, NIC, UZB
(6, 7]	KGZ, GNQ, ZWE, ARM, BOL, BIH, WSM, ALB, SLB, MDA, IDN, PHL
(7, 8]	GIN, SCG, HND, AZE, CIV, COG, CMR, LSO
(8, 9]	MNG, HTI, SYR, COM, MRT, SEN, KIR, LAO, STP, GMB
(9, 10]	TJK, BEN, GHA, IRQ, PRK, NPL, CAF, TGO, RWA, BTN, MLI, ZMB, KEN, GNB, TCD, BDI, YEM, MOZ, SLE
(10, 11]	BFA, NER, ERI, VNM†, MWI, PAK†, SOM, AFG, MDG, UGA, SDN, LBR
11 <	TZA†, KHM†, BGD†, CHN†, ZAR†, ETH†, NGA†, IND†

Notes: \* denotes OECD countries; U.S. distribution parameters (shape = 1.503, scale = 31124)

† countries do not satisfy the sufficient condition (11); PPE and FPE may not hold, values should be interpreted cautiously

Table 2: Percentage of losers in the U.S. (Lognormal distribution)

Percentage	Country codes (as from the Penn World Table Version 6.2)
= 0	AUS*, AUT*, BHS, BEL*, BMU, BRN, CAN*, CYP, DNK*, FIN*, FRA*, GER*, HKG, ISL*, IRL*, ISR, ITA*, JPN*, KOR*, KWT, LUX*, MAC, MLT, NLD*, NZL*, NOR*, PRT*, PRI, QAT, SGP, SVN*, ESP*, SWE*, CHE*, TWN, ARE, GBR*
(0, 1]	SAU, ANT, BHR, BRB, OMN, KNA, CZE*, ATG, MUS, GRC*, ARG, TTO, CHL, URY, MYS, SYC, PLW
(1, 2]	HUN*, EST, SVK, GAB
(2, 3]	HRV, LTU, RUS, BLR, ZAF, POL*, CRI, LVA, DMA
(3, 4]	PAN, BRA, MEX*, VEN, THA, LBN, VCT
(4, 5]	SWZ, BWA, LCA, TUN, COL, BGR, BLZ, DOM, TKM, KAZ
(5, 6]	PRY, TUR*, CUB, IRN, NAM, GRD, ROM, FJI, MKD, JAM, DZA, SLV
(6, 7]	ECU, SUR, UKR, PER, JOR, MDV, PNG, FSM, CPV
(7, 8]	GEO, GTM, DJI, LKA, EGY, GUY, MAR, TON, VUT, NIC, UZB, KGZ, GNQ, ZWE
(8, 9]	ARM, BOL, BIH, WSM, ALB, SLB, MDA, IDN†, PHL, GIN, SCG, HND, AZE, CIV, COG
(9, 10]	CMR, LSO, MNG, HTI, SYR, COM, MRT, SEN, KIR, LAO, STP, GMB
(10, 11]	TJK, BEN, GHA, IRQ, PRK, NPL, CAF, TGO, RWA, BTN, MLI, ZMB, KEN, GNB, TCD, BDI, YEM, MOZ, SLE, BFA, NER, ERI, VNM†, MWI, PAK†, SOM, AFG, MDG, UGA, SDN†
11 <	LBR, TZA†, KHM†, BGD†, CHN†, ZAR†, ETH†, NGA†, IND†

Notes: \* denotes OECD countries; U.S. distribution parameters (shape = 0.961, scale = 10.41)

† countries do not satisfy the sufficient condition (11); PPE and FPE may not hold, values should be interpreted cautiously

Table 3: Decomposition of welfare changes due to trade with Canada  
(Gamma distribution)

	Household income percentiles					
	10th	20th	50th	80th	90th	95th
Household income in U.S. dollars	10588	17601	42294	81719	112241	144636
Product diversity (%)	6.23	9.17	19.52	31.92	39.18	45.37
Pro-competitive effects (%)	93.77	90.83	80.48	68.08	60.82	54.63

Notes: U.S. distribution parameters (shape = 1.503, scale = 31124). Household income in U.S. dollars is taken from the U.S. Census Bureau, Current Population Survey 1997 Annual Social and Economic Supplements.