On Measuring the Welfare Gains from Trade under Consumer Heterogeneity

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Abstract

I develop a multi-country multi-industry model of trade that features heterogeneous consumers with non-homothetic preferences. I use the model to quantify the measurement errors in the welfare gains estimates caused by the assumption of a representative consumer (ARC). First, I reduce the world level of all trade costs by 15% and find that ARC overestimates (underestimates) the gains of the poor (rich) by up to 12 (9) percentage points. Second, I eliminate import tariffs around the globe and show that (i) the loss of tariff revenues is not negligible for some consumers and (ii) the measurement errors from ARC are between -6 and 12 percentage points.

Keywords: General equilibrium; Welfare gains; Non-homotheticity; Heterogeneous consumers

JEL-codes: F1; F10; F17

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1 Introduction

Surveys frequently point to the enormous heterogeneity in individual attitudes towards free trade policies. While majority of relatively rich and educated individuals seem to favor lowering barriers to trade, up to 80% of the poor do not feel helped by globalization and consistently oppose free trade policies.[1] What is the reason for this large gap between the poor and the rich in terms of their views on the potential benefits from international trade?

Conventional wisdom suggests that the reason for this disparity is broadly related to the Stolper-Samuelson-type effects when people with different skills, abilities or employment statuses experience heterogeneous effects of trade on their earnings.[2] I argue, however, that even in the absence of asymmetric wage effects, the welfare gains from trade are highly heterogeneous across consumers due to consumer-specific price effects. For instance, in 2006 in the United States, 32% of consumers believed that Free Trade Agreements would lead to a decrease in domestic prices, while 30% believed they would increase them and 23% expected no significant change. This large degree of heterogeneity of opinions suggests that people consume different bundles of goods and that the price effects of trade liberalization may be asymmetric across those bundles. I develop a general equilibrium model of trade that comes to grips with these two features by combining consumer heterogeneity, non-homothetic preferences and sector-specific trade elasticity parameters. I argue that the conventional *assumption of a representative consumer* (ARC) completely ignores the heterogeneity in the price effects which leads to significant quantitative and qualitative deviations of the welfare gains calculated under ARC from true consumer-specific welfare gains.

I calibrate the model to data on 92 countries and structurally estimate the model's parameters. The calibrated model suggests that (i) there is a larger heterogeneity in technologies in the manufacturing sector relative to the agricultural sector, and that (ii) rich consumers spend larger share of their total income on manufacturing goods and services.[3] These two insights imply that an equal reduction in trade costs for both manufacturing and agricultural goods would offer relatively higher welfare gains to the rich. I use the model to conduct two counterfactual trade liberalization experiments and demonstrate that the welfare gains

[1] See Pew Research Center Survey from December, 2006.

[2] So far in the literature, income effects (through different wages) have been the main source of heterogeneity in the welfare gains from trade. For example, Artuc, Chaudhuri, McLaren (2010) use a dynamic labor adjustment model and estimate how trade liberalization affects different types of workers. Helpman, Itskhoki and Redding (2008, 2010) explore the link between wages, income inequality and unemployment in general equilibrium models of trade with heterogenous firms and workers. McLaren and Hakobyan (2010) use US Census data to estimate local welfare effects for heterogenous workers from joining NAFTA.

[3] That rich and poor consumers have different consumption patterns is a well established fact. For example, see Broda and Romalis (2009); Broda, Leibtag and Weinstein (2009); Faber (2012).

from trade largely differ both qualitatively and quantitatively across individuals.

In the first experiment, I assume that there is an exogenous and costless 15% reduction of trade costs in the world. Under this scenario, ARC overestimates true welfare gains of the poor by up to 12 percentage points and underestimates the gains of the rich by up to 9 percentage points. Such dispersion is extremely large considering that the welfare gains estimates under ARC lie between 1% and 22%. In the second experiment, I globally abolish import tariffs such that the trade liberalization is costly as consumers have to lose a fraction of their total income equal to tariff revenues. In this case, the measurement errors from ARC are between -6 and 12 percentage points with many predictions under ARC being qualitatively wrong. Overall, I find that the the second experiment results in lower welfare gains for all countries. This is driven by (i) the loss of tariff revenues and (ii) the observed asymmetry in the import tariff matrices, when relatively higher tariffs are imposed on agricultural goods (lower elasticity of trade) especially by the poor countries. I also show that the latter has important implications for the welfare gains from trade since even when the size of tariff revenues is close to negligible (relative to total GDP), assuming away the distributional effects of the trade liberalization costs is not innocuous.

In the next section, I discuss the contribution of this work relative to the existing literature. In Section 3, I present the model and illustrate the fundamental problem with ARC under non-homothetic preference structure and heterogenous consumers. In Section 4, I estimate the parameters of the model and describe the calibration procedure. Section 5 discusses exact sources of heterogeneity in the welfare gains from trade. I conduct a counterfactual trade liberalization experiment to assess the validity of the predictions under ARC and to calculate consumer-specific welfare gains in Section 6. The final section offers a brief conclusion.

2 Related Literature

Until recently, much of theoretical and empirical work assumed homothetic preferences and homogenous consumers.[4]The former assumption implies that consumption patterns are identical across countries i.e. relative consumption shares are independent of the level of income. On the other hand, irrespective of how preferences are specified, consumer homogeneity implies that consumption patterns are identical within each country as they are

[4]Notable exceptions are Jackson (1984), Markusen (1986), Flam and Helpman (1987), Bergstrand (1990), Hunter (1991), Matsuyama (2000). For additional discussion on why non-homotheticity of preferences is important for trade see Markusen (2010).

captured by a single representative consumer.

Recent trade models tackle the assumption of homotheticity of preferences using different variants of Eaton and Kortum (2002) and Melitz (2003). For example, Fieler (2011) argues that non-homotheticity is important for explaining North-South and South-South trade patterns. Caron, Fally and Markusen (2012) use non-homothetic preferences to examine the link between the skill premium and income elasticity of demand.[5] Both models are based on a multi-industry version of Eaton and Kortum (2002) and in that sense are closely related to the model here. However, there are several important differences that distinguish this work from other Eaton-Kortum-type trade models that feature non-homothetic preferences.[6]

First and foremost, I argue that even under non-homothetic preferences welfare gains of an average consumer largely differ from individual consumer gains. Fieler (2011) and Caron, Fally and Markusen (2012) emphasize the role of per-capita income with a single representative consumer in mind.[7] Hence, they correct for consumption differences across countries but not across consumers within each country. However, within country differences in consumption bundles between the poorest and the richest consumer are often much larger than between average consumers in the poorest and the richest country, respectively. I argue that ARC under non-homothetic (or homothetic) preferences introduces large measurement errors in the welfare gains from trade for consumers within each country.

Second, change in prices due to trade liberalization is governed by the trade elasticity parameter (Frechèt dispersion parameter in Eaton-Kortum-type models). Sectors with lower productivity dispersion parameters would experience relatively larger decrease in prices. Since rich consumers spend disproportionately larger share of their income on manufac-

[5]Other examples include Simonovska (2010) who shows that non-homothetic preference structure helps explaining pricing-to-market patterns across countries and Tombe (2012) who uses non-homothetic preferences to explain missing trade in food.

[6]There is a growing body of work that looks at the link between non-homotheticity, product quality and international trade (Hallak, 2006; Verhoogen, 2008; Khandewal, 2010; Davis and Harrigan, 2011). For example, Hummels and Klenow (2005) and Hallak and Schott (2011) found that richer countries import and export goods of higher quality. Fajgelbaum, Grossman and Helpman (2011) formulate a model with non-homothetic preferences, horizontal and vertical product diffentiation. Although, the model here does not feature vertical product differentiation and has little to say about product quality and trade, it does capture important patterns observed in the data, e.g., rich consumers spend larger share of total income on goods produced in the manufacturing and service sectors.

[7]Admittedly, Fieler (2011) and Caron, Fally and Markusen (2012) briefly discuss possible extensions of their models to include consumer heterogeneity (see Section 5.1 and Section 5.4, respectively). However, these two papers do not discuss consumer-specific welfare gains and dismiss the importance of consumer heterogeneity for the question at hand, namely explaining trade flows. The focus of the paper here is not in explaining trade flows *per se* but rather in evaluating how welfare gains from trade differ across heterogeneous consumers.

turing and services than on agricultural goods, cross-sectoral differences in trade elasticity parameters are central determinants of the gains from trade of the rich versus the poor. I find that the productivity dispersion is lower in the agricultural sector (e.g. apples versus milk) than in manufacturing (e.g. computers versus shirts). Then, the model immediately implies that trade liberalization would offer higher benefits to the rich. Relative to Caron, Fally and Markusen (2012) who assume identical productivity dispersion parameter across all sectors, this is a novel channel that explains heterogeneity of welfare gains from trade.

Third, input-output data suggests that firms use output from other sectors as intermediate inputs with manufacturing (e.g. cars) and non-tradable goods (e.g. financial services) being used relatively more extensively. Including these input-output linkages in quantitative trade models is essential for evaluating welfare gains correctly (see Caliendo and Parro, 2010; Ossa, 2011). Trade liberalization makes manufacturing input relatively cheaper and the price of non-tradable goods decreases. As rich consumers also spend disproportionately larger share on services than on food, they again benefit relatively more from free trade. This reinforces the result above. Neither Fieler (2011) nor Caron, Fally and Markusen (2012) consider this channel in their benchmark models.

Many general equilibrium models of international trade feature worker heterogeneity and look at the distributional effects of trade through the prism of Stolper-Samuelson-type effects (see Egger and Kreickermeier, 2009; Helpman, Itskhoki and Redding, 2010; Harrigan and Reshef, 2012). In these models, heterogeneity of wages comes from heterogeneity of firms' productivities and the employment draw of each consumer completely determines her relative gains from trade. For example, Davis and Harrigan (2011) introduce labor market frictions into a variant of Melitz (2003) model and show that while trade liberalization raises *average* wage, it negatively impacts workers that had relatively high wages in pre-trade equilibrium. Burstein and Vogel (2012) and Parro (*forthcoming*) formulate Ricardian models and examine the effect of trade on income inequality through the skill premium. In contrast to these two strands of the literature, the model here emphasizes the demand channel and shows that even when relative factor rewards do not change, workers experience heterogeneous effects of trade liberalization. Hence, in many ways this work is complementary to the literature above as consumer-specific price indices are required to correctly evaluate the welfare gains from change in wages induced by a trade liberalization.

Finally, this work is related to two empirical case studies based on micro data, Porto (2006) and Broda and Romalis (2009). The former is based on survey data and uses econometric (rather than general equilibrium) approach to calculate welfare gains from joining MERCOSUR for different consumer groups along the income distribution. Broda and Romalis

(2009), use price scan data for the US and argue that consumer-specific price indices are essential for measuring real income inequality. In contrast to these two works that consider individual countries and specific policy scenarios, I provide more structural approach via a general equilibrium model that incorporates multiple sectors and many countries and can be applied to multiple counterfactual scenarios. To the best of my knowledge, in the context of consumer-specific price indices, this is the first structural attempt to measure the extent of heterogeneity in the welfare gains from trade in such setting.

3 Model

There are J countries in the world. Each country $i = (1,\dots,J)$ is endowed with L_i units of labor which is inelastically supplied to a measure of heterogeneous firms in the agricultural, manufacturing and non-tradable sectors.[8]Manufacturing and agricultural goods can be traded subject to sector-specific iceberg trade costs from j to i, $\tau_{m,ij} \geq 1$ and $\tau_{a,ij} \geq 1$, respectively.[9]Labor is assumed to be completely mobile across sectors but not countries.

I introduce consumer heterogeneity in the spirit of Mayer (1984) by assuming that households own different shares of total labor, L_i. Households can be of type $d = (1,...,10)$, where d stands for the decile in the distribution of total labor force (and income) such that $\sum_{d=1}^{10} L_{id} = L_i$.[10]For example, in 1996 in the United States the bottom decile owned 1.73% of total income which is translated into the model as $L_{USA,10} = 0.0173$. There are many ways to interpret heterogeneity across households in terms of their labor endowments. For example, Blanchard and Willmann (2011) assume differences in abilities, Costinot and Vogel (2010) point to the importance of skill intensities, and Bougheas and Riezman (2007) assume heterogeneous levels of human capital.

The preference structure is non-homothetic which ensures that differences in the level of real income are mapped into the differences in consumption patterns across deciles and countries such that some consumers may choose not to consume (or consume little) of certain goods. Both extensive and intensive margins of import demand are important.[11]

[8] I follow Alvarez and Lucas (2007) and assume that labor reflects *equipped labor*.

[9] The usual triangularity (no arbitrage) assumption applies.

[10] I use deciles to approximate the distribution of labor endowments, simply because no data are available on a more disaggregated level. On the other hand, using less disaggregated measures such as quartiles or quintiles could convolute the differences between the poor and the rich to the point when income inequality is no longer as important.

[11] Many general equilibrium models of trade deliver isomorphic predictions in terms of welfare gains from trade (see Arkolakis, Costinot and Rodriguez-Clare, 2010). The two necessary conditions for this remarkable result are – CES demand system and structural gravity equation. This model deviates in two major ways:

3.1 Households

Households of type $d = (1, \ldots, D)$ in country i maximize consumption of the non-tradable good, n_i, the tradable manufacturing good, m_i, and the tradable agricultural good, a_i, according to the following nested Stone-Geary utility function:

$$U(n_i, m_i, a_i) = (n_i^{\beta} m_i^{1-\beta} + \mu)^{\alpha} a_i^{1-\alpha} \text{ s.t. } L_{id} w_i = n_i p_{ni} + m_i p_{mi} + a_i p_{ai}, \tag{3.1}$$

where p_{ni}, p_{mi} and p_{ai} are prices of the non-tradable, manufacturing, and agricultural goods, respectively and w_i is wage rate per unit of labor. The utility function in (3.1) captures non-homotheticity of preferences through the term μ, which can be interpreted as endowment of non-tradable and manufacturing goods. The preference structure ensures that *before* consuming non-tradable and manufacturing goods each consumer must spend certain amount of her income on food. The cut-off level of income is specified as follows:

$$W_i^* = \frac{\mu(1-\alpha)}{\alpha\beta} \left(\frac{\beta}{1-\beta} \frac{p_{mi}}{p_{ni}} \right)^{1-\beta} \tag{3.2}$$

As long as consumer d has income higher than in (3.2), which is sufficient to buy some positive amount of manufacturing and non-tradable aggregates, her final demands are given by:

$$n_{id} = \frac{\alpha\beta \left(L_{id} w_i - W_i^* \right)}{p_{ni}}; \quad m_{id} = \frac{\alpha(1-\beta) \left(L_{id} w_i - W_i^* \right)}{p_{mi}}; \quad a_{id} = \frac{L_{id} w_i (1-\alpha) + \alpha W^*}{p_{ai}}. \tag{3.3}$$

Otherwise, she buys zero manufacturing and non-tradable goods and spends all her income on food.

The preference structure in (3.1) relate import demand to trade and are consistent with the empirical literature on the link between international trade, per-capita income and income inequality. The model predicts positive relationship between income inequality and trade (especially in poor countries) and positive relationship between average per-capita income and trade (see Goldberg and Pavcnik 2004, 2007; Dalgin, Trindade and Mitra, 2008; Harrison, McLaren and McMillan, 2010).

consumer heterogeneity and non-homothetic preferences. The combination of these two guarantees that the predictions of the model here differ from the canonical models of trade (Eaton and Kortum, 2002; Anderson and van Wincoop, 2003; Bernard, Jensen, Eaton and Kortum, 2003; Melitz, 2003) and provides novel insights.

3.2 Heterogeneity in welfare gains: basic idea

I focus on one particular type of heterogeneity in the welfare gains from trade that comes from consumer-specific price indices. For that, I shut down the income effect in a sense that upon an arbitrary trade liberalization consumers experience proportional changes in their nominal incomes. This allows me to quantify differences in welfare gains across consumers that accrue purely to changes in relative prices.

The conjecture here is that the extent of heterogeneity in the welfare gains from trade is extremely large. Given the price vector, $\{p_{ni}, p_{mi}, p_{ai}\}$, in country i, I can derive the indirect utility function using the Marshallian demands in (3.3):

$$V(L_{id}w_i, p_{ni}, p_{mi}, p_{ai}) = \begin{cases} \left(\dfrac{B(L_{id}w_i - W_i^*)}{p_{ni}^{\beta} p_{mi}^{1-\beta}} + \mu\right)^{\alpha} \left(\dfrac{L_{id}w_i - \alpha(L_{id}w_i - W_i^*)}{p_{ai}}\right)^{1-\alpha} & \text{if } L_{id}w_i > W_i^* \\ \mu^{\alpha} \left(\dfrac{L_{id}w_i - \alpha(L_{id}w_i - W_i^*)}{p_{ai}}\right)^{1-\alpha} & \text{if } L_{id}w_i \leq W_i^*, \end{cases} \tag{3.4}$$

where $B = \alpha(1-\beta)^{1-\beta}\beta^{\beta}$. It is straightforward to see that non-homothetic preferences and consumer heterogeneity imply unequal welfare gains. Under a hypothetical trade liberalization consumers in i will face different (endogenously determined) wage rate, w_i', and price vector, $\{p_{ni}', p_{mi}', p_{ai}'\}$. In order to measure changes in welfare, I employ the concept of *equivalent variation*,[12] EV_{id}, defined as the additional income at pre-trade liberalization prices $\{p_{ni}, p_{mi}, p_{ai}\}$ necessary to make consumer d in country i indifferent between the pre- and post-liberalization equilibria:

$$V(L_{id}w_i + EV_{id}, p_{ni}, p_{mi}, p_{ai}) = V(L_{id}w_i', p_{ni}', p_{mi}', p_{ai}'). \tag{3.5}$$

To make welfare gains comparable across consumers I normalize EV_{id} with the initial level of income, $L_{id}w_i$, and argue that.[13]

$$\frac{EV_{id}}{L_{id}w_i} \neq \frac{EV_{ig}}{L_{ig}w_i} \quad \text{for consumers } d \neq g. \tag{3.6}$$

In other words, as long as there is inequality in the level of labor endowments and non-identical change in prices across different sectors, non-homotheticity will ensure that the

[12] The results are robust to alternative metrics such as *compensating variation* and/or percentage change in welfare.

[13] It is customary to work with the expenditure function to calculate EV_{id}. However, solving for EV_{id} analytically could be extremely challenging, so I choose to calculate it numerically directly from (3.5).

welfare gains from trade vary across consumers.

3.3 Production

I model production in the spirit of Eaton and Kortum (2002) because multi-country Ricardian models calibrated to real data mimic both aggregate trade flows and average levels of real income per capita with high accuracy.[14]This allows me to provide clear quantitative predictions in the counterfactual section that have straightforward interpretation relative to the benchmark data.

Each country is endowed with a fixed measure of labor. In addition, firms employ Spence-Dixit-Stiglitz (SDS hereafter) aggregates of the non-tradable and manufacturing goods, and firms in the agricultural sector also employ the SDS aggregate of the agricultural goods. Modeling production with these three sectors is motivated by the data from the aggregate input-output tables. Including intermediate inputs and a non-tradable sector is important to identify welfare gains correctly (see Goldberg, Khandelwal, Pavcnik and Topalova, 2009; Caliendo and Parro, 2010).[15]

Manufacturing sector

Each country hosts a measure of firms, each with a productivity parameters drawn from a Frechèt distribution. The productivity is a realization of a random variable z_{mi} distributed according to:

$$F_{mi}(z_{mi}) = \exp\left(-\lambda_{mi} {z_{mi}}^{-\theta_m}\right), \tag{3.7}$$

here λ_{mi} is country-specific productivity parameter and θ_m – dispersion parameter common across all countries. Each firm in the sector employs labor, non-tradable and manufacturing aggregates in the following way:

$$m_i(q) = z_{mi}(q) l_i(q)^{\xi} \left(n_i(q)^{\zeta} m_i(q)^{1-\zeta}\right)^{1-\xi}, \tag{3.8}$$

[14]For example, see Alvarez and Lucas (2007); Egger and Nigai (2012). Different variants of the multi-country Ricardian models have also been used to study multinational production. For instance, see Ramondo and Rodriguez-Clare (2012) and Arkolakis, Ramondo, Rodriguez-Clare and Yeaple (2012).

[15]Consistent with the literature and the OECD classification I classify industries in three broad sectors: agricultural goods, manufacturing goods and non-tradable goods. The SDS aggregates are produced according to conventional CES technology with the elasticity parameters $1-\sigma_a$ and $1-\sigma_m$ for the agricultural and manufacturing sectors, respectively.

where q denotes different varieties. The probabilistic representation of technologies allows deriving the average variable cost of a producer of a manufacturing variety in country i:

$$\kappa_{mi} = \Gamma_m \lambda_{mi}^{-\frac{1}{\theta_m}} w_i^{\xi} \left(p_{ni}^{\zeta} p_{mi}^{1-\zeta} \right)^{1-\xi}, \tag{3.9}$$

where Γ_m is a sector-specific constant. The average variable cost, κ_{mi}, along with the sector-specific iceberg trade costs, $\tau_{m,i\ell}$, and the ad-valorem tariff rate, $t_{m,i\ell}$, are sufficient to derive the aggregate price of tradables in i as follows:

$$p_{mi} = \left(\sum_{\ell}^{N} (\kappa_{m\ell} \tau_{m,i\ell} t_{m,i\ell})^{-\theta_m} \right)^{-\frac{1}{\theta_m}}. \tag{3.10}$$

Agricultural sector

Each firms in the agricultural sector has a total factor productivity parameter drawn from a country-specific productivity distribution:[16]

$$F_{ai}(z_{ai}) = \exp\left(-\lambda_{ai} z_{ai}^{-\theta_a} \right). \tag{3.11}$$

The respective expression of the production function of an agricultural variety h in i is:

$$a_i(h) = z_{ai}(h) l_i(h)^{\gamma} \left(n_i(h)^{\epsilon} m_i(h)^{\rho} a_i(h)^{1-\epsilon-\rho} \right)^{1-\gamma}. \tag{3.12}$$

An important feature of the production of agricultural goods is their dependence on the aggregate agricultural input. This is not the case for the firms in the non-tradable and manufacturing sectors.[17]This modeling choice is consistent with the input-output data on the production linkages in the three sectors. The price of the agricultural aggregate can be expressed using average variable cost in i's partner countries, $\kappa_{a\ell}$, iceberg trade costs specific to that sector, $\tau_{a,in}$, and import tariff, $t_{a,in}$:

$$p_{ai} = \left(\sum_{\ell}^{N} (\kappa_{a\ell} \tau_{a,i\ell} t_{a,in})^{-\theta_a} \right)^{-\frac{1}{\theta_a}}. \tag{3.13}$$

[16]The productivity distributions of the tradable and the agricultural sectors are identical in terms of the family class but not the underlying parameters. I estimate the parameters for each of them in the following sections.

[17]This approach is consistent with Caliendo and Parro (2011) who use input-output tables to account for the inter-dependence across industries. My formulation simply uses information from the input-output tables on a more aggregate level.

Non-tradable sector

As standard in the literature (e.g. see Alvarez and Lucas, 2007) I assume that each country has a representative firm in the non-tradable sector producing non-tradable output using constant-returns-to-scale technology:

$$n_i = l(n)_i^{\phi} \left(n_i(n)^{\varrho} m_i(n)^{1-\varrho}\right)^{1-\phi}, \tag{3.14}$$

accordingly the price of the non-tradable good is:

$$p_{ni} = \Gamma_n w_i^{\phi} (p_{ni}^{\varrho} p_{mi}^{1-\varrho})^{1-\phi}, \tag{3.15}$$

where Γ_n is a sector-specific constant.[18]

3.4 International trade

International trade occurs in the manufacturing and agricultural sectors. Countries can produce identical sets of varieties but the productivity draw for each variety is a realization of a random draw from a country-specific productivity distribution. Hence, countries compete vis-à-vis each other given their productivity distribution parameters, factor prices and barriers to trade. Bilateral trade flows, $X_{m,ij}$ and $X_{a,ij}$, can be decomposed into three components:

$$X_{m,ij} = x_{m,ij} S_{mi}(L_i w_i), \quad \text{and} \quad X_{a,ij} = x_{a,ij} S_{ai}(L_i w_i), \tag{3.16}$$

here $x_{m,in}$ and $x_{a,in}$ are the supply side components of total trade flows, and $L_i w_i$ corresponds to the observable aggregate GDP (and w_i is average per-capita income). As in Eaton and Kortum (2002) they represent the share of country j in country i's total imports of manufacturing and agricultural goods, respectively.

$$x_{m,ij} = \frac{(\kappa_{mj}\tau_{m,ij}t_{m,ij})^{-\theta_m}}{\sum_{\ell}^{J}(\kappa_{m\ell}\tau_{m,i\ell}t_{m,i\ell})^{-\theta_m}}, \quad \text{and} \quad x_{a,ij} = \frac{(\kappa_{aj}\tau_{a,ij}t_{a,ij})^{-\theta_a}}{\sum_{\ell}^{J}(\kappa_{a\ell}\tau_{a,i\ell}t_{a,i\ell})^{-\theta_a}} \tag{3.17}$$

[18]Here, I assume that countries do not differ in terms of productivities of the non-tradable sector. This is harmless because I solve the model in changes using real data. Hence, technology parameters are pinned down by the data in the benchmark and I assume that they remain constant throughout.

An important difference between the models based on homothetic demand structures and the model here is that the income consumption shares, S_{mi} and S_{ai}, differ across countries. In other words, x_{mi} and x_{ai} are not sufficient to derive bilateral trade flows because country-level income shares are not constant. The model here features final and intermediate demand for the aggregates of all three sectors. Hence, country-level income consumption shares, S_{ni}, S_{mi} and S_{ai}, must be calculated as the sum of the consumers' and producers' demands on non-tradable, manufacturing and agricultural goods, respectively.

I use individual consumer demand equations in (3.3) to aggregate them into country level final demands as follows:

$$N_i = \sum_{d=1}^{10} \left\{ \mathbf{1}_{L_{id} w_i > W_i^*} \right\} \alpha\beta \left(L_{id} w_i - W_i^*\right); \tag{3.18}$$

$$M_i = \sum_{d=1}^{10} \left\{ \mathbf{1}_{L_{id} w_i > W_i^*} \right\} \alpha(1-\beta) \left(L_{id} w_i - W_i^*\right); \tag{3.19}$$

$$A_i = \sum_{d=1}^{10} \left\{ \mathbf{1}_{L_{id} w_i > W_i^*} \right\} L_{id} w_i (1-\alpha) + \alpha W_i^* + \left\{ \mathbf{1}_{L_{id} w_i \leq W_i^*} \right\} L_{id} w_i, \tag{3.20}$$

where $\left\{ \mathbf{1}_{L_{id} w_i > W_i^*} \right\}$ is an indicator function. Notice that total import demand for the agricultural and manufacturing goods, A_i and M_i, depend on the average level of income and income inequality. For example, in rich countries with average income, w_i, all consumers are above the subsistence level. On the other hand, in poor countries where income of some consumers is below or close to W_i^*, income distribution is a central determinant of total import demand. First, total trade is increasing in the average level of per-capita income as all consumers, in both rich and poor countries, spend higher share of their income on manufacturing goods that are relatively more prevalent in international trade. Second, higher income inequality, even more so in poor countries, leads to higher demand for the manufacturing goods. Higher dispersion of L_{id} effectively means that richer consumers, who spend relatively more on manufacturing goods, hold higher share of total country's income which increases total import demand.

The second component of total import demand is firms' spending on intermediates which is proportional to total output of the non-tradable, agricultural and manufacturing sectors and can be calculated as total consumption minus net exports in the respective sector. Let me use D_{ai} and D_{mi} to denote net exports (observed in the data) in the agricultural and manufacturing sectors, respectively. I can then define the following system of equations for each country i:

$$\underbrace{\begin{pmatrix} S_{ni}(L_i w_i) \\ S_{mi}(L_i w_i) \\ S_{ai}(L_i w_i) \end{pmatrix}}_{\text{Sectoral Absorption}} = \underbrace{\begin{pmatrix} (1-\phi)\varrho & (1-\phi)(1-\varrho) & 0 \\ (1-\xi)\zeta & (1-\xi)(1-\zeta) & 0 \\ (1-\gamma)\epsilon & (1-\gamma)\rho & (1-\gamma)(1-\epsilon-\rho) \end{pmatrix} \begin{pmatrix} S_{ni}(L_i w_i) \\ S_{mi}(L_i w_i) D_{mi} \\ S_{ai}(L_i w_i) - D_{ai} \end{pmatrix}}_{\text{Intermediate Demand}} + \underbrace{\begin{pmatrix} N_i \\ M_i \\ A_i \end{pmatrix}}_{\text{Final Demand}} . \tag{3.21}$$

With observations on $L_i w_i$ (which is equivalent to GDP) at hand, it is straightforward to recover S_{ni}, S_{mi} and S_{ai}. To close the model, I assume that *total* imports equal *total* exports such that the trade is multilaterally balanced up to observed constants D_{mi} and D_{ai}:

$$L_i w_i \sum_{j=1}^{J} \left(S_{mi} x_{m,ij} + S_{ai} x_{a,ij}\right) + D_{mi} + D_{ai} = \sum_{j=1}^{J} L_j w_j \left(S_{mj} x_{m,ji} + S_{aj} x_{a,ji}\right). \tag{3.22}$$

Closing the model in this way is in the spirit of Dekle, Eaton and Kortum (2007). Ossa (2011) points to the importance of specifying trade imbalances correctly in relation to the reciprocity principles in trade agreement negotiations. In the counterfactual experiment I exogenously change tariffs which leaves no room for strategic tariff setting. For this reason, I choose to follow Dekle, Eaton and Kortum (2007) and keep D_{mi} and D_{ai} constant relative to the world GDP and normalize all income values such that the average per-capita income in the USA is unity throughout this paper.

In contrast to the models with homothetic preferences and/or homogeneous consumers, here both average per-capita income, w_i, and income distribution parameters, L_{id}, enter country-level demands. As it turns out, these structural links have two major consequences for international trade and consumer welfare. First, S_{mi} and S_{ai} capture the link between average per-capita income (captured by w_i), income distribution (captured by the distribution of L_{id}) and international trade flows. Second, depending on within-country distribution of the labor endowment, L_{id}, different consumers within each country place different welfare weights on the consumption of n_i and m_i versus a_i. This ensures that under asymmetric production and technological parameters between the three sectors, an arbitrary trade liberalization leads to heterogeneous welfare effects.

4 Calibration

I calibrate the model to 92 countries in the world.[19]The reference year for all the data is 1996. I describe the data sources in the Appendix.

For the counterfactual experiment I need to calibrate the parameters of the utility function and the production functions in the three sectors. I also need to estimate θ_m and θ_a. I solve for the counterfactual values in the spirit of Dekle, Eaton and Kortum (2007) and do not have to estimate λ_{mi}, λ_{ai}, $\tau_{m,ij}$, and $\tau_{a,ij}$. The details of the solution method are available in the Appendix.

4.1 Parameters of the utility function

Calculating β, which governs the ratio of the consumption of non-tradable to manufacturing goods, is straightforward given the data on households' spending. This share is constant across countries and does not vary much with the average level of per capita income. The intuition is that once consumer surpasses the subsistence level of income the ratio stays constant:

$$\frac{\beta}{1-\beta} = \frac{1}{J}\sum_{i=1}^{J}\frac{N_i}{M_i} \tag{4.1}$$

The calculated average is (1.96) with standard deviation of (0.62) which implies $\beta = 0.38$.

Estimating the remaining two parameters α and μ is more challenging because, unlike β, the share of income spent on agricultural goods is not constant across consumers and countries. I calibrate α and μ to match the data on country level spending shares $\left(\frac{A_i}{L_i w_i}\right)$. To estimate these parameters, I minimize the squared distance between country-level expenditure shares predicted by the model as described in (3.20) in Section 3.1 and data as follows:

$$\min_{\alpha,\mu}\sum_{i=1}^{J}\left[\ln\left(\frac{A_i}{L_i w_i}\right) - \ln\left(\widehat{\frac{A_i}{L_i w_i}}\right)\right]^2 \text{ s.t. } \alpha \in [0,1], \tag{4.2}$$

where $\left(\frac{A_i}{L_i w_i}\right)$ are the data and $\left(\widehat{\frac{A_i}{L_i w_i}}\right)$ are the model's prediction. Here A_i is a function

[19]The limitations of the data do not allow me to extend the sample further. However, the 92 countries in the sample include all large economies in the world. Hence, the calibrated model is very close to reflecting the world in economic terms.

of α and μ, which given the value of β, the data on $L_{id}w_i$ and prices, is calculated as in (3.20). Solving (4.2) yields $\alpha = 0.9062$ and $\mu = 0.0274$. The calibrated model predicts that the average level of the threshold across countries is 51.5 US dollars per annum with standard deviation of 71.5.

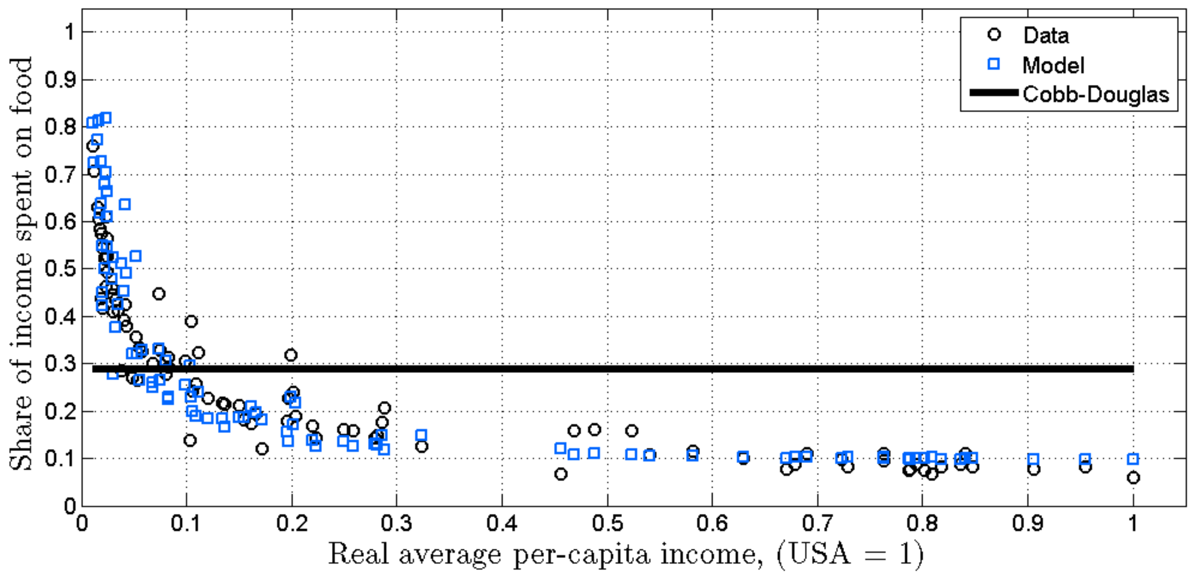

Figure 1: Expenditure Ratios versus Average Real Income per Capita

The share of income spent on agricultural goods varies tremendously across countries and is consistently correlated with the real income of an average household in country i. Hence, non-homotheticity is necessary to model total import demand of manufacturing and agricultural goods correctly. In Figure 1, I plot the data on the aggregate income shares spent on agricultural goods versus average per-capita real income as well as the model's prediction under non-homothetic and homothetic preferences. Under Cobb-Douglas preferences the share of income spent on food would be constant across countries and is represented by the solid horizontal line. Clearly, this assumption is at odds with the data for all countries in the sample. On the other hand, the calibrated model that features non-homothetic preferences closely follow the patterns observed in the data. The correlation between the model's prediction and the data is 0.92.

Figure 1 suggests that non-homotheticity is a necessary condition to correctly predict total consumer demand for manufacturing goods in each country. However, I also argue that in order to evaluate welfare gains for different consumer groups within each country one has to account for consumer heterogeneity. In Figure 2, I plot the model's prediction on income shares spent on food for different deciles. Notice that the degree of consumption heterogeneity in poor countries is extremely acute. In fact, the gap between the richest and the poorest consumer in some countries is at least as big as the gap between average consumers in the richest and the poorest country. This suggests that non-homotheticity alone is not sufficient to evaluate consumer-specific welfare gains correctly.

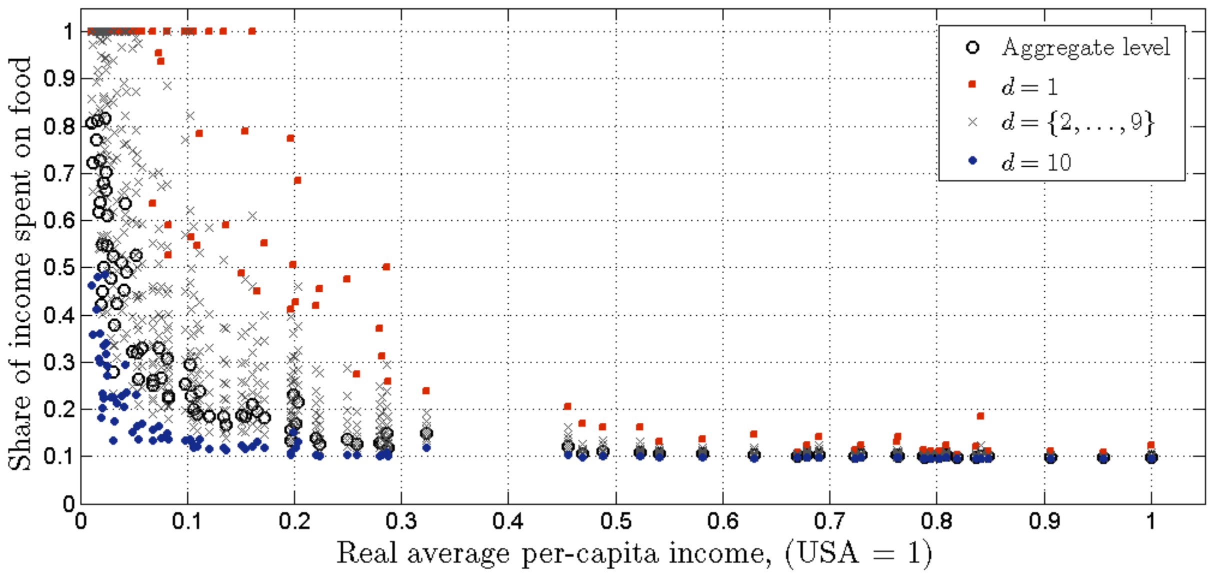

Figure 2: EXPENDITURE RATIOS VERSUS AVERAGE REAL INCOME PER CAPITA

The differences in the income shares spent on agricultural goods are especially large for developing countries which is intuitive given that they are often characterized by low average level of income and high dispersion thereof. The subsistence level is binding for the poorest consumers in a number of developing countries but never for the richest consumers. The differences are less acute, yet still substantial, for relatively rich countries.

4.2 Parameters of the production functions

The production parameters are calculated using input-output tables as follows. Parameters $\{\phi, \xi, \gamma\}$ govern the share of value added in the non-tradable, manufacturing and agricultural sectors, respectively. I calculate them as a ratio of value added to the total output in the respective sector. Similarly, parameters $\{\varrho, \zeta, \epsilon, \rho\}$ are calculated from the ratio of total non-tradable input to total manufacturing input. Cross-country averages with standard deviations of these parameters are in Table 1.

I estimate the trade elasticities in the manufacturing and the agricultural sectors – θ_m and θ_a– using the data on trade flows and tariffs. Let me normalize manufacturing trade flow from j to i, $X_{m,ij}$, by the value of domestic sales to get a familiar structural gravity equation:

Table 1: PRODUCTION PARAMETERS

	ϕ	ξ	γ	ϱ	ζ	ϵ	ρ
mean	0.5474	0.2919	0.4995	0.6822	0.3154	0.2780	0.3829
std.deviation	0.0574	0.0363	0.1101	0.1046	0.0842	0.0778	0.1243
N	39	39	39	39	39	39	39

Notes: The parameters were calculated using the data on Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, China, Czech Rep., Denmark, Estonia, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, Korea, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, UK, USA, Vietnam. The data for other countries in the sample were unavailable.

$$\frac{X_{m,ij}}{X_{m,ii}} = \left(\frac{\kappa_n \tau_{m,ij} t_{m,ij}}{\kappa_i}\right)^{-\theta_m} \text{ where } \tau_{m,ij} = (\tau_{m,i} \tilde{\tau}_{m,ij} \tau_{m,j}). \tag{4.3}$$

I assume that total trade costs $\tau_{m,ij}$ are log-additive with tariffs and that they consist of an exporter-specific asymmetric component – $\tau_{m,j}$, an importer specific asymmetric component – $\tau_{m,i}$, and a symmetric component $\tilde{\tau}_{m,ij}$. The two asymmetric trade cost components will be captured by the respective fixed effects. Consistent with the literature, I proxy for the symmetric component of trade costs $\tilde{\tau}_{m,ij}$ using a measure of bilateral distance and an adjacency dummy:

$$\ln(\tilde{\tau}_{m,ij}) = \psi_1 \text{adjacency}_{ij} + \psi_2 \ln(\text{distance}_{ij}) \tag{4.4}$$

Then, I estimate the following stochastic version of (4.3):

$$\frac{X_{m,ij}}{X_{m,ii}} = \exp\left\{ex_j + im_i - \theta_m \ln(t_{m,ij}) - \theta_m \ln(\tilde{\tau}_{m,ij})\right\} + error_{ij}, \tag{4.5}$$

here im_i and ex_j are catch-all importer and exporter fixed effects, respectively. Notice that the coefficient on tariffs between i and j identifies θ_m.[20]

I estimate θ_a using the data on $X_{a,ij}$ and $t_{a,ij}$ in the same fashion. I choose to estimate (4.5) in levels rather than in logs to avoid the problem of zeros.[21] In practice, I maximize

[20] Caliendo and Parro (2011), Ramondo and Rodriguez-Claire (2009), Egger and Nigai (2011, 2012) use tariffs to identify the elasticity of trade. The critique of Simonovska and Waugh (2011) is not particularly pertinent to the methodology here because: (i) I do not use price data for identification of the trade elasticity and (ii) the results for manufacturing sector are reasonably close to Simonovska and Waugh (2011) and other estimates in the literature.

[21] For example, see Baldwin and Harrigan (2011), Chor (2010).

Table 2: PRODUCTION PARAMETERS

parameter	estim.	std. error	parameter	estim.	std. error
ψ_1^a	0.164	0.224	ψ_1^m	0.615	0.183
ψ_2^a	-0.438	0.073	ψ_2^m	-0.322	0.066
θ^a	-12.072	1.160	θ^m	-6.539	1.235

Notes: Standard errors are based on Eicker-White sandwich estimates and are robust to heteroskedasticity of an unknown form.

the respective Poisson Pseudo Maximum Likelihood function as advocated by Santos Silva and Tenreyro (2006). The estimates of $\theta_m = 6.53$ and $\theta_a = 12.07$ along with the respective standard errors are reported in Table 2.[22]

The estimated values of θ_a and θ_m are in line with the literature. Fieler (2010) also finds that the degree of heterogeneity in technology is less pronounced in less income elastic goods and uses the values of 8.3 and 14.3, respectively. Donaldson, Costinot and Komunjer (2012) use productivity data in the manufacturing sector and estimate $\theta = 6.5$.

5 Sources of heterogeneity in the welfare gains

Benchmark values of θ_m and θ_a suggest that the degree of heterogeneity in productivities is much lower in the the agricultural sector.In terms of the productivity distributions, this means that in the agricultural sector a higher mass of firms is concentrated around the mean. On the other hand, the manufacturing sector exhibits higher mass of firms in the right tail of the productivity distribution. This is depicted in Figure 3 where I plot two Frèchet distributions with identical scale parameter ($\lambda = 10$) but different θ's.

That trade elasticity parameters inversely determine the welfare gains from trade is a well established result (see Arkolakis, Costinot and Rodriguez-Clare, 2010). Intuitively, with lower θ the number of firms with high productivity (low prices) is larger which means that a reduction in trade barriers leads to a relatively sharper decrease in prices. On the other hand very high θ means that more firms are centered around the mean and the response of prices to a change in trade barriers would be less acute. Mechanically, this is captured in price equations for the agricultural and manufacturing sectors in (3.13) and (3.10), respectively.

[22] As a sensitivity check, I used distance dummies rather than ln(distance$_{ij}$). The estimates are insensitive to such alternative specifications of symmetric trade costs.

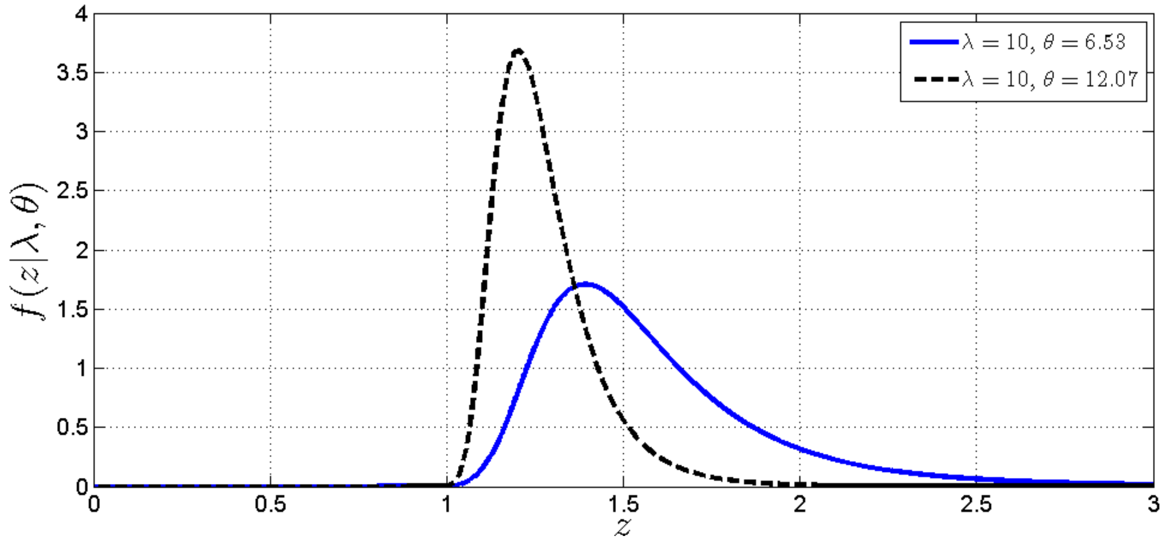

Figure 3: EXAMPLES OF FRÈCHET DISTRIBUTIONS

Here, the model captures three separate sources of heterogeneity in the welfare gains from trade:

(i) **Dispersion of productivity parameters:** $\theta_m < \theta_a$. Equivalent reduction in trade barriers leads to higher decrease in the price of the manufacturing goods, p_m, relative to the price of the agricultural goods, p_{ai}.

(ii) **Intermediate inputs:** $(1-\zeta)(1-\xi) > \rho(1-\gamma)$. Firms in the manufacturing sector use manufacturing aggregate as intermediate input relatively more intensively. On the other hand, firms in the agricultural sector use output of the agricultural sector more intensively. Hence, the result in (i) is amplified by asymmetry in the intensity of the intermediate inputs and p_{mi}, p_{ni} experience larger decrease relative to p_{ai}.

(iii) **Expenditure shares:** $\frac{m_{id}}{L_{id}w_i} \leq \frac{m_{ig}}{L_{ig}w_i}$, $\frac{n_{id}}{L_{id}w_i} \leq \frac{n_{ig}}{L_{ig}w_i}$ and $\frac{a_{id}}{L_{id}w_i} \geq \frac{a_{ig}}{L_{ig}w_i}$ if $L_{id} \leq L_{ig}$ for consumers d and g. Rich consumers in every country spend relatively higher share of their income on the manufacturing goods. Hence, under a symmetric reduction in trade barriers, as a result of (i) and (ii), relatively richer consumers will experience relatively higher welfare gains.

I next turn to quantifying the heterogeneity in the welfare gains from trade that result from (i), (ii) and (iii).

6 Counterfactual experiments

For the counterfactual experiment, it is useful to express the model in relative changes. Let a denote benchmark and a' - counterfactual value of some variable, then the relative change is $\widehat{a} = a'/a$. I assume that the primitives of the model τ_{ij} and λ_i do not respond to indirect shocks such that $\widehat{\tau}_{ij} = 0$ and $\widehat{\lambda}_{ij} = 0$ (unless otherwise noted) and conduct counterfactual experiments without having to estimate these unobservable fundamentals. The counterfactual outcomes are calculated in the spirit of Dekle, Eaton and Kortum (2007). Details on how to apply their approach in models with non-homothetic preferences as well as description of the computational procedures are available in the Appendix.

I conduct two counterfactual experiments. First, I globally reduce trade costs by 15% and assume that this reduction is costless. In the second experiment, I globally eliminate *all* tariffs while acknowledging the fact that consumers are hurt by the loss of tariff revenues. The two experiment are close to each other in terms of the total reduction in trade barriers as in the benchmark year the average import tariff was about 15%. However, they have different implications for consumer welfare which suggests that accounting for policy-implementation costs is important when evaluating counterfactual outcomes.

The main purpose of this work is to quantify the measurement error from ARC. In order to do that, I calculate each counterfactual outcome for d different consumers and one representative consumer (with average GDP per capita) in each country. First, I calculate *equivalent variation* and deflate it by pre-liberalization level of income in each of the two scenarios. Then, I use Δ to denote the percentage of the initial income that consumer d has gained (lost) because of trade liberalization:

$$\bar{\Delta}_i = 100 \times \left(\frac{EV_i}{w_i} \right) \text{ and } \Delta_{id} = 100 \times \left(\frac{EV_{id}}{L_{id} w_i} \right), \tag{6.1}$$

where $\bar{\Delta}_i$ is the percentage change in welfare under ARC and Δ_{id} is the percentage change in welfare for consumer d in country i. The difference between the two, $\bar{\Delta}_i - \Delta_{id}$, measures by how many percentage points ARC *overestimates* true welfare gains from trade.

6.1 Global reduction in trade costs

In the first counterfactual experiment I reduce *all* trade costs by 15% such that the counterfactual change in trade costs is specified as:

$$\widehat{\tau}_{ij} = \begin{cases} 0.85 \text{ if } i \neq j \\ 1 \quad \text{if } i = j. \end{cases} \tag{6.2}$$

Under this scenario, I calculate *equivalent variation*, EV_{id}, for each consumer d in country i. This experiment is *clean* in a sense that *all* distortions come from an exogenous and costless reduction in trade costs. This allows me to pin down the extent of heterogeneity in the welfare gains from trade due to consumer-specific price effects only.

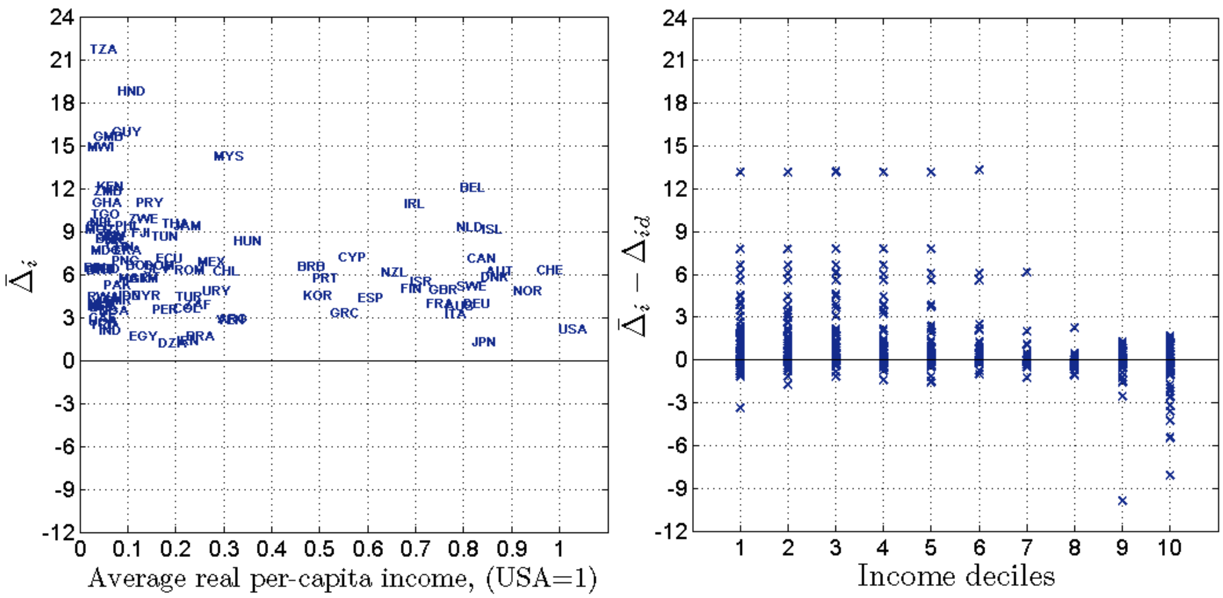

Figure 4: RESULTS OF EXPERIMENT 1

First, I calculate the welfare gains for an average consumer (with income equal to the average per-capita income) as specified in (6.1). I plot the results in the left panel of Figure 4. The results indicate that average consumers in all countries would gain from a costless trade liberalization. Smaller countries tend to gain relatively more which is consistent with the literature (see Alvarez and Lucas, 2007). On average welfare gains vary between 1% and 22% for poor and between 1 and 12% for rich countries.

Next, I calculate the measurement error induced by ARC. Suppose, a policy maker evaluates the gains from trade using a measure consistent with ARC, $\bar{\Delta}_i$. I calculate by how many percentage points she would overpredict true welfare gains of consumer d: $\bar{\Delta}_i - \Delta_{id}$. I plot these errors for each income decile in the right panel of Figure 4. ARC tends to overpredict welfare gains for the lowest seven deciles and to underpredict the gains for the highest three deciles. The magnitude of the errors is large. For the consumers in the left tail of the income

Table 3: COUNTERFACTUAL CHANGE IN VARIABLES IN % (EXPERIMENT 1)

	$\bar{\Delta}_i$	Δ_{i1}	Δ_{i2}	Δ_{i3}	Δ_{i4}	Δ_{i5}	Δ_{i6}	Δ_{i7}	Δ_{i8}	Δ_{i9}	Δ_{i10}	w_i	p_{ai}	p_{ni}	p_{mi}
ARG	2.891	2.879	2.880	2.883	2.873	2.890	2.892	2.892	2.898	2.901	2.907	3.452	1.799	2.533	-0.894
AUS	3.752	3.686	3.739	3.747	3.749	3.752	3.755	3.757	3.759	3.762	3.762	2.669	0.692	1.489	-2.877
AUT	6.162	6.135	6.153	6.157	6.160	6.161	6.165	6.167	6.166	6.170	6.174	3.158	-0.734	1.265	-5.625
BDI	6.463	6.458	6.468	6.465	6.410	6.492	6.465	6.467	4.197	5.333	9.710	9.585	2.930	5.267	-9.668
BEL	12.045	12.026	12.038	12.043	12.046	12.047	12.049	12.051	12.052	12.054	12.058	9.629	-0.519	5.920	-7.084
BEN	8.473	5.446	7.562	7.901	8.042	8.206	8.345	8.460	8.585	8.722	8.914	1.692	-3.549	-1.025	-10.715
BFA	3.722	1.545	1.593	1.611	1.723	1.592	1.608	1.700	4.112	3.367	2.893	-4.029	-5.533	-4.880	-8.051
BGD	6.373	2.913	2.908	2.770	2.921	6.470	6.428	6.393	6.358	6.320	6.268	3.078	0.164	1.123	-5.982
BOL	6.643	4.698	4.699	6.354	6.470	6.540	6.581	6.622	6.655	6.695	6.741	2.589	-2.013	0.545	-6.866
BRA	1.651	1.547	1.599	1.614	1.626	1.633	1.637	1.642	1.647	1.650	1.655	0.821	-0.318	0.313	-1.596
BRB	6.544	6.490	6.531	6.525	6.536	6.539	6.542	6.544	6.546	6.548	6.551	0.403	-5.457	-1.487	-8.358
CAF	2.981	2.023	3.181	2.024	2.034	2.021	1.775	2.897	3.006	3.089	3.205	-1.546	-3.508	-2.547	-6.263
CAN	7.114	7.077	7.095	7.102	7.105	7.109	7.110	7.112	7.114	7.116	7.118	5.285	0.563	3.077	-4.911
CHE	6.304	6.247	6.287	6.293	6.296	6.299	6.302	6.304	6.307	6.315	6.313	3.974	0.200	2.019	-5.093
CHL	6.192	6.356	6.256	6.213	6.204	6.198	6.198	6.198	6.200	6.204	6.217	5.339	1.321	3.395	-3.682
CHN	7.933	3.433	5.344	6.168	6.756	7.191	7.565	7.871	8.172	8.487	8.971	7.343	1.889	4.384	-6.151
CIV	8.743	12.088	10.474	9.934	9.516	9.231	8.987	8.782	8.576	8.410	8.160	9.684	2.333	7.161	-1.923
CMR	4.203	2.717	2.749	5.084	4.766	4.552	4.391	4.267	4.164	4.079	3.983	3.685	0.945	2.453	-2.107
COL	3.632	2.587	3.222	3.374	3.457	3.516	3.560	3.717	3.629	3.665	3.709	1.024	-1.659	-0.102	-4.275
CYP	7.213	7.163	7.193	7.201	7.207	7.212	7.215	7.221	7.223	7.227	7.233	-1.040	-5.946	-3.136	-10.714
DEU	3.912	3.901	3.908	3.910	3.912	3.913	3.914	3.914	3.915	3.916	3.916	2.119	-0.685	0.923	-3.499
DNK	5.832	5.793	5.820	5.823	5.826	5.828	5.829	5.831	5.832	5.840	5.835	4.834	0.149	3.044	-3.496
DOM	6.583	5.453	6.055	6.252	6.369	6.452	6.520	6.573	6.614	6.658	6.722	3.712	-1.736	1.677	-5.710
DZA	1.210	1.477	1.361	1.300	1.269	1.241	1.225	1.210	1.196	1.185	1.165	-10.317	-11.206	-10.628	-11.802
ECU	7.114	4.905	7.883	7.582	7.405	7.292	7.213	7.155	7.100	7.057	7.023	6.927	1.937	4.721	-3.266
EGY	1.661	-0.361	0.059	0.588	0.936	1.183	1.399	1.577	1.740	1.900	2.094	-7.176	-8.812	-7.777	-10.031
ESP	4.323	4.285	4.301	4.308	4.308	4.310	4.312	4.313	4.315	4.317	4.320	1.909	-1.310	0.601	-4.224
ETH	6.304	6.294	6.444	6.302	6.312	6.309	6.301	6.307	6.196	5.052	10.591	6.844	0.510	2.482	-12.550
FIN	5.022	5.008	5.017	5.021	5.023	5.025	5.027	5.029	5.030	5.032	5.036	3.613	0.430	2.050	-3.686
FJI	8.864	10.014	9.439	9.218	9.099	9.008	8.942	8.886	8.836	8.791	8.739	8.655	0.956	5.949	-3.749
FRA	3.962	3.942	3.951	3.954	3.956	3.958	3.959	3.960	3.962	3.962	3.965	2.193	-0.622	0.982	-3.498
GBR	4.902	4.878	4.895	4.899	4.902	4.905	4.906	4.909	4.910	4.912	4.915	2.196	-1.086	0.698	-4.806
GHA	11.017	8.951	8.951	6.389	7.779	9.102	10.115	10.940	11.715	12.486	13.626	9.906	0.877	5.324	-10.431
GMB	15.609	16.047	16.076	16.050	14.147	11.905	13.561	14.614	15.473	16.144	16.658	11.256	-4.128	6.217	-10.962
GRC	3.272	3.215	3.250	3.259	3.265	3.267	3.268	3.270	3.272	3.274	3.276	-1.872	-4.361	-2.830	-6.389
GTM	5.733	3.837	4.463	4.958	5.231	5.416	5.557	5.667	5.757	5.855	5.965	4.136	-0.710	2.305	-4.377
GUY	15.946	15.599	13.989	14.678	15.080	15.401	15.635	15.963	15.960	16.101	16.382	14.141	-2.180	9.098	-8.141
HND	18.791	16.864	15.838	12.673	14.996	16.428	17.508	18.339	19.192	19.692	20.559	13.861	-2.533	7.467	-13.752
HTI	6.394	5.107	5.133	5.085	5.088	5.085	5.144	7.654	6.478	5.392	4.702	-2.730	-7.437	-3.963	-8.515
HUN	8.315	8.342	8.320	8.312	8.315	8.305	8.308	8.308	8.308	8.315	8.312	5.066	0.153	2.491	-6.741
IDN	4.533	4.432	4.467	4.484	4.499	4.505	4.514	4.522	4.532	4.542	4.566	2.461	-0.502	1.052	-4.138
IND	2.051	1.343	0.991	1.108	1.388	1.613	1.788	2.041	2.217	2.428	2.745	2.872	1.491	1.891	-1.757
IRL	10.934	10.905	10.920	10.927	10.931	10.935	10.938	10.939	10.943	10.946	10.950	9.840	1.041	6.426	-5.626
IRN	1.361	-0.219	0.566	0.849	1.022	1.152	1.202	1.342	1.415	1.486	1.574	-3.935	-5.020	-4.406	-6.177
ISL	9.155	9.017	9.117	9.139	9.148	9.153	9.157	9.160	9.163	9.165	9.167	9.538	2.472	6.645	-3.686
ISR	5.502	5.430	5.463	5.477	5.486	5.510	5.497	5.501	5.504	5.508	5.513	2.044	-1.423	0.366	-5.771
ITA	3.212	3.186	3.197	3.199	3.200	3.201	3.197	3.202	3.203	3.203	3.205	1.804	-0.726	0.832	-2.782
JAM	9.366	8.837	9.114	9.211	9.338	9.300	9.326	9.348	9.365	9.381	9.401	4.641	-3.674	1.854	-8.092
JPN	1.261	1.260	1.260	1.261	1.260	1.260	1.260	1.261	1.261	1.261	1.261	-0.307	-1.431	-0.682	-2.096
KEN	12.097	5.462	5.442	5.461	5.468	13.598	12.859	12.299	11.790	11.337	10.692	8.154	2.551	4.854	-6.809
KOR	4.503	4.403	4.479	4.493	4.499	4.503	4.505	4.509	4.511	4.513	4.517	1.944	-0.832	0.559	-4.545
LKA	7.685	8.695	8.278	8.081	7.961	7.869	7.792	7.718	7.655	7.586	7.481	4.775	-1.181	2.518	-5.635
MAR	5.712	5.896	5.825	5.784	5.758	5.742	5.730	5.718	5.704	5.695	5.686	2.561	-1.952	0.854	-5.386
MDG	7.693	3.859	3.856	3.858	3.854	3.857	7.831	7.704	7.607	7.521	7.405	4.532	0.650	2.230	-6.078
MEX	6.883	6.711	6.793	6.823	6.841	6.857	6.868	6.880	6.891	6.904	6.923	4.670	0.138	2.529	-5.227
MLI	3.962	3.059	2.560	3.073	3.062	3.065	3.068	3.554	3.931	4.259	4.766	-0.866	-3.811	-2.325	-7.683
MOZ	9.095	9.711	9.511	9.553	9.511	9.513	8.702	8.744	10.155	11.686	14.554	6.089	-3.125	1.021	-16.148
MWI	14.866	7.122	7.115	7.098	7.083	7.113	14.238	14.960	14.667	14.368	13.841	8.573	1.378	4.326	-10.373
MYS	14.266	12.454	13.345	13.680	13.872	14.016	14.129	14.221	14.302	14.376	14.476	11.382	1.418	6.832	-8.847
NER	3.782	1.612	1.599	1.634	1.595	1.443	1.614	3.817	3.600	3.387	3.186	-5.743	-7.221	-6.662	-10.075
NGA	3.431	2.991	2.985	2.941	2.997	2.996	3.009	2.961	3.679	4.397	5.429	-1.330	-4.200	-3.105	-9.571
NIC	8.405	7.699	5.188	6.493	7.195	7.637	7.974	8.225	8.467	8.681	8.983	6.708	-0.954	3.934	-5.980
NLD	9.314	9.289	9.309	9.311	9.313	9.316	9.316	9.317	9.318	9.319	9.321	7.054	-0.968	4.215	-5.921
NOR	4.803	4.771	4.790	4.795	4.798	4.801	4.803	4.804	4.806	4.806	4.811	1.909	-0.865	0.432	-4.996
NPL	9.576	3.498	3.481	3.476	3.583	3.471	3.472	3.457	9.410	8.994	8.277	5.144	1.618	2.624	-6.425
NZL	6.132	5.982	6.085	6.103	6.114	6.122	6.129	6.151	6.141	6.151	6.153	6.589	2.484	4.642	-2.446
PAK	5.202	2.868	5.253	5.239	5.234	5.221	5.194	5.207	5.198	5.190	5.177	2.287	-0.568	0.684	-5.189
PER	3.491	3.660	3.565	3.537	3.500	3.512	3.506	3.501	3.498	3.495	3.494	1.748	-1.257	0.698	-3.197
PHL	9.404	9.668	9.553	9.438	9.500	9.439	9.421	9.408	9.399	9.394	9.404	5.105	-0.865	2.220	-8.051
PNG	6.973	5.935	6.474	6.676	6.779	6.844	6.934	6.982	7.056	7.119	7.191	6.832	1.027	4.560	-3.654
PRT	5.703	5.654	5.678	5.684	5.689	5.693	5.696	5.697	5.699	5.702	5.708	1.297	-3.166	-0.395	-6.582
PRY	10.994	6.942	7.971	9.355	9.907	10.362	10.630	10.862	11.080	11.264	11.522	4.997	-2.310	1.483	-10.849
ROM	6.252	6.279	6.252	6.250	6.250	6.250	6.253	6.251	6.252	6.253	6.258	2.443	-1.434	0.534	-6.411
RWA	4.443	4.445	4.876	4.443	4.585	4.446	4.093	4.321	4.671	5.022	5.566	1.956	-2.383	0.145	-6.460
SEN	8.645	6.472	9.241	9.051	8.921	8.860	8.736	8.664	8.596	8.526	8.411	4.053	-2.274	1.535	-7.503
SLE	9.344	9.345	9.317	9.403	9.338	9.367	9.346	9.345	9.324	19.222	17.471	9.491	0.134	4.469	-12.626
SLV	6.334	5.490	5.620	5.931	6.034	6.181	6.255	6.312	6.330	6.407	6.470	2.930	-2.425	0.985	-6.086
SWE	5.163	5.143	5.156	5.159	5.161	5.163	5.165	5.167	5.168	5.170	5.178	3.631	0.320	2.028	-3.850
SYR	4.503	5.366	4.951	4.775	4.272	4.617	4.563	4.522	4.492	4.451	4.427	-4.083	-7.052	-5.361	-10.070
TCD	2.491	2.106	2.183	2.089	2.094	2.102	2.201	2.457	2.705	2.987	3.364	-0.974	-3.018	-2.123	-6.377
TGO	10.146	7.481	7.494	7.074	8.131	8.943	9.345	10.195	10.680	11.389	12.390	6.281	-1.113	2.125	-12.259
THA	9.554	10.366	9.996	9.874	9.760	9.680	9.622	9.577	9.541	9.522	9.510	7.488	2.175	4.487	-6.189
TUN	8.623	8.840	8.716	8.691	8.665	8.647	8.634	8.631	8.616	8.614	8.609	4.187	-1.555	1.573	-7.790
TUR	4.422	4.105	4.257	4.320	4.359	4.388	4.411	4.428	4.445	4.453	4.486	0.410	-2.026	-0.958	-5.997
TZA	21.703	8.526	8.518	8.510	8.514	8.521	8.399	21.661	21.231	20.766	20.154	11.082	2.364	4.990	-15.289
UGA	2.741	3.894	3.894	3.914	4.147	3.894	0.249	1.610	2.948	4.339	6.378	7.364	3.342	5.012	-3.478
URY	4.803	4.810	4.798	4.793	4.794	4.795	4.795	4.798	4.801	4.804	4.809	4.181	0.682	2.692	-2.783
USA	2.161	2.133	2.150	2.154	2.157	2.158	2.159	2.161	2.161	2.162	2.164	0.000	-1.116	-0.667	-3.165
VEN	2.771	1.949	2.462	2.598	2.668	2.715	2.749	2.775	2.796	2.814	2.837	-2.959	-4.845	-3.792	-6.897
ZAF	3.822	3.073	3.461	3.570	3.676	3.684	3.722	3.754	3.797	3.813	3.923	0.295	-1.934	-0.905	-5.339
ZMB	11.805	6.250	6.223	6.255	6.235	6.205	6.257	12.169	11.799	11.448	11.001	6.364	0.127	2.988	-8.908
ZWE	9.824	5.405	5.413	5.407	5.415	11.430	10.809	10.356	9.997	9.750	9.457	5.698	0.276	2.775	-7.631

distribution, the *overprediction* errors are between -3 and 13 percentage points. This is substantial given that the average welfare gains are between 1 and 22%. The measurement errors are a bit smaller, though still very significant relative to the average welfare gains, for consumers in the richest deciles and vary between -9 and 2 percentage points.

Results in the right panel of Figure 4 are mainly driven by poor and more unequal countries. This is intuitive because in poor and more unequal countries higher share of consumers are close to the threshold level of income. These consumers derive relatively higher utility from agricultural goods. As I argued before, technological dispersion parameters, $\theta_a > \theta_m$, imply that an equal reduction in trade costs would result in higher decrease in prices for

manufacturing goods relative to agricultural goods. This prediction is confirmed in Table 4 where I report the results of Experiment 1. Manufacturing prices decrease more relative to the agricultural and non-tradable goods in *all countries*. Accordingly, the poor in more unequal and less developed countries benefit relatively less from global reduction in trade costs. On the other hand, in rich countries *all* consumers are above the subsistence level of income and the measurement errors from ARC in those countries are less pronounced.

6.2 Global elimination of tariffs

In this counterfactual experiment, I globally eliminate all import tariffs to assess the effect of this hypothetical policy on consumers welfare. In the benchmark year, tariffs were not symmetric with poor countries imposing relatively higher tariffs especially in the agricultural sector. Hence, the counterfactual elimination of all tariffs involves changes in the following manner:

$$t'_{a,ij} = 1 \text{ and } t'_{m,ij} = 1 \text{ such that } \widehat{t}_{a,ij} = (t_{a,ij})^{-1}; \widehat{t}_{m,ij} = (t_{m,ij})^{-1} \text{ for all } i,j. \tag{6.3}$$

The degree of asymmetry in tariffs is quite substantial. Average import tariffs in the agricultural and manufacturing sectors are 18.33% and 11.02%, respectively.

Trade liberalization is a costly process. In Experiment 1, I assumed that all trade costs are exogenously reduced by 15% at zero policy cost. This, of course, is highly unlikely and I consider Experiment 2 to be more policy relevant. Here, I assume that the cost of trade liberalization is (at least partially) captured by the loss of tariff revenues. This should provide a lower bound of relevant policy costs.

Often tariff revenues are not considered to be of first-order importance for welfare. However,

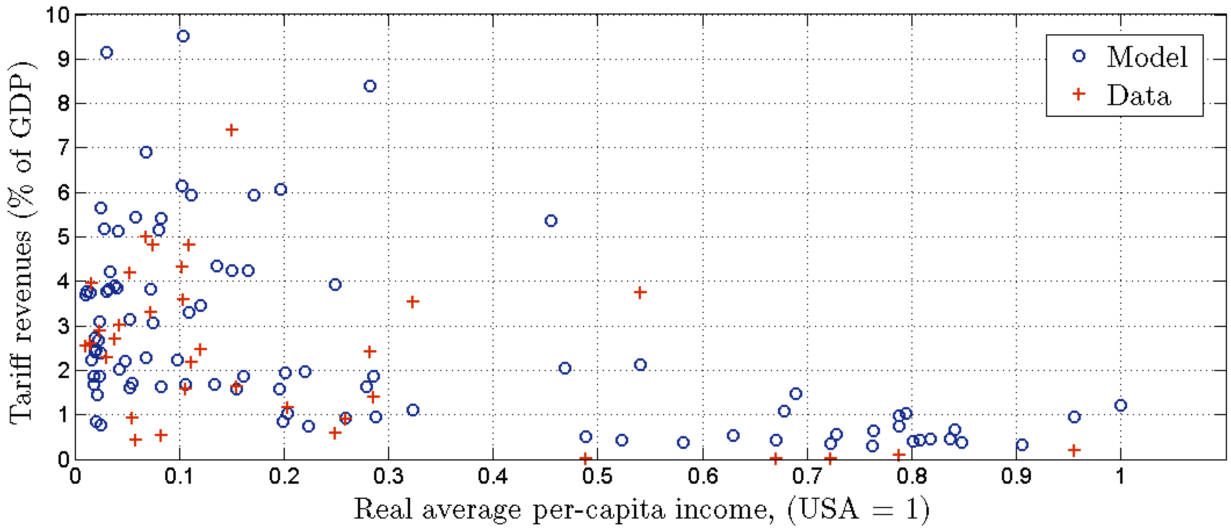

Figure 5: TARIFF REVENUES

the data indicate that the share of tariff revenues in total GDP is not innocuous. In Figure 5, I plot the share of tariff revenues as % of GDP using data (where available) and model's predictions. The data suggest that for some poor countries, such as Tunisia, tariff revenues constitute to more than 7% of total GDP. Naturally, for most rich countries, the share of tariff revenues in total expenditure is fairly small. The model's predictions are very much in line with the data in terms of both magnitude and correlation patterns between per-capita income and the relative size of tariff revenues observed in the data. One should not expect perfect correlation because the model uses simple sector-exporter-importer specific averages of ad valorem tariffs while in data the revenues are likely to be formed in a more complex way. Nevertheless, the model is doing a good job in predicting the average level (and share of total GDP) of total import tariff revenues.

Upon global abolishment of tariffs each country loses *all* tariff revenues. I calculate the size of the revenue loss using data on bilateral trade flows and tariffs as follows:

$$R_i = \sum_{j=1}^{J} \left((t_{m,ij} - 1) X_{m,ij} + (t_{a,ij} - 1) X_{a,ij} \right), \tag{6.4}$$

where $X_{m,ij}$ and $X_{a,ij}$ are data on trade flows in the manufacturing and agricultural sectors, respectively. I assume that tariff revenues were distributed proportionally to L_{id} such that all consumers lose the same share of their benchmark nominal income. An alternative distribution scheme would be lump-sum transfers. This assumption would only reinforce my results as lump-sum transfers would mean that the poor depend on tariff revenues relatively more. Hence, I choose to be conservative and assume that R_i is distributed as follows:

$$R_{id} \propto L_{id} \text{ such that } \sum_i R_{id} = R_i. \tag{6.5}$$

With R_{id} at hand I can calculate post-liberalization level of income for each consumer as $L_{id}w'_i - R_{id}$. This has implications for wages and prices that are endogenous to consumer income as the market clearing condition becomes:

$$(L_i w'_i - R_i)\sum_{j=1}^{J}\left(S'_{mi}x'_{m,ij} + S'_{ai}x'_{a,ij}\right) + D_{mi} + D_{ai} = \sum_{j=1}^{J}(L_j w'_j - R_j)\left(S'_{mj}x'_{m,ji} + S'_{aj}x'_{a,ji}\right). \tag{6.6}$$

Country level spending shares S'_{ai}, S'_{mi} and S'_{ni} are also endogenous to R_{id} from individual demand equations (3.18) and (3.20).

I calculate the welfare gains for an average consumer in each country and plot them in the left panel of Figure 6. Here, there are major differences from the results in Experiment 1. Welfare gains of an average consumer are now smaller everywhere and especially in rich countries. Average consumers in some countries experience negative welfare gains. The main reason for the disparities between the results in Experiment 1 and Experiment 2 is twofold.

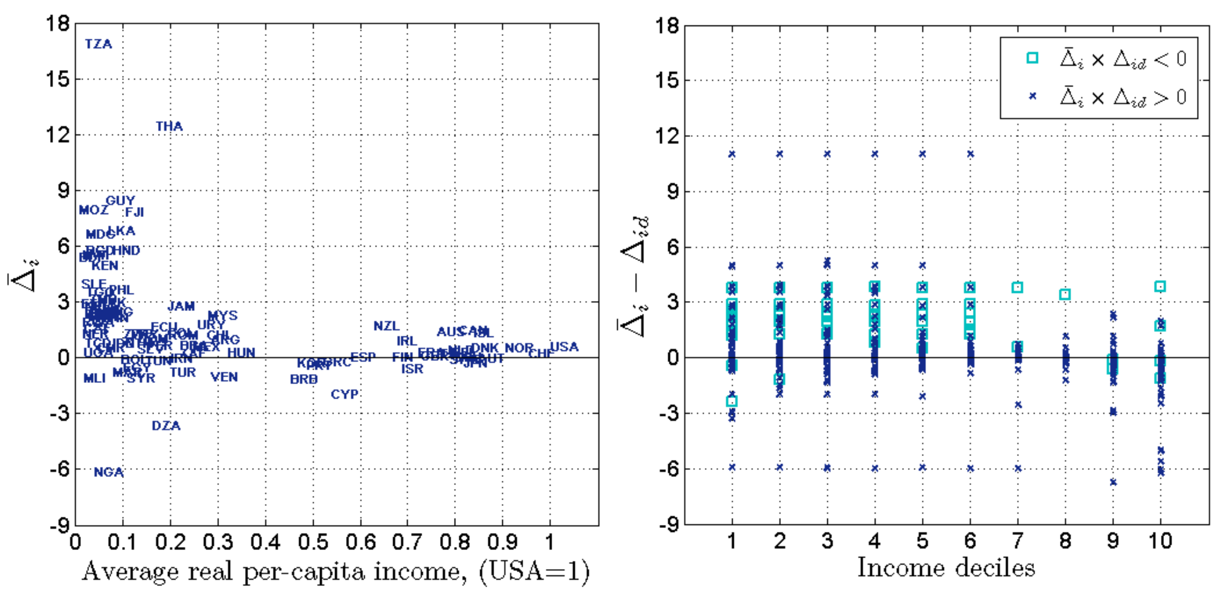

Figure 6: Results of Experiment 2

Table 4: COUNTERFACTUAL CHANGE IN VARIABLES IN % (EXPERIMENT 2)

	$\bar{\Delta}_i$	Δ_{i1}	Δ_{i2}	Δ_{i3}	Δ_{i4}	Δ_{i5}	Δ_{i6}	Δ_{i7}	Δ_{i8}	Δ_{i9}	Δ_{i10}	w_i	p_{ai}	p_{ni}	p_{mi}
ARG	0.940	0.962	0.943	0.943	0.939	0.944	0.943	0.944	0.946	0.950	0.954	3.263	2.325	2.652	0.360
AUS	1.381	1.341	1.370	1.375	1.377	1.379	1.383	1.382	1.381	1.381	1.387	5.869	4.948	5.210	2.741
AUT	-0.080	-0.070	-0.075	-0.087	-0.076	-0.076	-0.078	-0.079	-0.086	-0.079	-0.082	-0.118	-0.926	-0.193	-0.480
BDI	5.343	5.327	5.339	5.329	5.334	5.340	5.348	5.336	4.204	5.809	10.968	4.302	-4.501	-1.520	-20.855
BEL	0.280	0.298	0.289	0.282	0.284	0.283	0.282	0.280	0.279	0.278	0.269	1.716	-0.906	1.370	0.065
BEN	2.291	-0.191	1.576	1.793	1.954	2.085	2.195	2.284	2.386	2.490	2.641	1.512	-2.545	-0.683	-8.610
BFA	2.311	-1.493	-1.490	-1.454	-1.512	-1.485	-1.477	-1.488	2.559	1.574	0.570	-7.622	-8.950	-8.624	-12.337
BGD	5.772	1.937	1.879	1.928	1.897	5.453	5.600	5.736	5.873	6.023	6.275	2.529	-1.770	-0.227	-10.056
BOL	-0.120	-0.939	-0.915	-0.932	-0.609	-0.409	-0.278	-0.181	-0.089	-0.020	0.059	-1.082	-2.422	-1.813	-4.543
BRA	0.610	0.598	0.600	0.600	0.603	0.607	0.612	0.616	0.601	0.627	0.629	1.971	1.287	1.538	-0.093
BRB	-1.171	-1.030	-1.092	-1.117	-1.133	-1.147	-1.160	-1.169	-1.168	-1.193	-1.219	-3.801	-12.315	-4.934	-9.126
CAF	1.591	-1.292	-1.310	-1.278	-1.257	-1.285	-1.308	2.226	1.302	0.683	-0.088	-7.287	-8.575	-7.981	-10.574
CAN	1.421	1.423	1.419	1.419	1.419	1.419	1.420	1.427	1.418	1.418	1.420	4.656	2.954	4.083	1.933
CHE	0.190	0.220	0.204	0.201	0.194	0.197	0.197	0.194	0.192	0.193	0.191	1.452	-0.851	1.149	0.005
CHL	1.180	1.278	1.217	1.199	1.194	1.189	1.176	1.187	1.187	1.181	1.196	3.180	1.737	2.281	-1.068
CHN	2.141	-0.416	0.069	0.737	1.188	1.534	1.838	2.102	2.349	2.609	3.019	3.350	-1.709	0.569	-9.350
CIV	2.341	1.699	3.430	3.010	2.807	2.629	2.486	2.366	2.267	2.148	1.997	4.932	1.600	3.850	-0.166
CMR	0.520	0.091	0.088	-0.779	-0.322	-0.001	0.240	0.423	0.577	0.710	0.877	-1.385	-3.665	-2.339	-5.885
COL	1.301	-0.541	0.607	0.877	1.029	1.129	1.206	1.260	1.313	1.360	1.420	3.196	1.043	2.256	-1.244
CYP	-2.001	-1.632	-1.830	-1.892	-1.931	-1.962	-1.985	-2.012	-2.034	-2.062	-2.101	-6.773	-17.680	-6.448	-5.199
DEU	0.010	0.010	0.010	0.010	0.008	0.006	0.005	0.004	0.001	0.002	0.002	0.163	-0.672	0.057	-0.347
DNK	0.490	0.510	0.494	0.493	0.491	0.490	0.489	0.489	0.488	0.487	0.482	2.866	1.075	2.611	1.646
DOM	1.021	-0.363	0.354	0.578	0.742	0.837	0.923	0.984	1.048	1.109	1.202	1.365	-2.155	-0.389	-6.789
DZA	-3.662	-3.373	-3.496	-3.558	-3.601	-3.618	-3.639	-3.665	-3.681	-3.701	-3.715	-13.582	-14.506	-13.905	-15.125
ECU	1.631	0.330	1.783	1.749	1.684	1.663	1.661	1.635	1.628	1.621	1.622	2.578	0.363	1.486	-2.566
EGY	-0.540	-5.466	-4.485	-3.173	-2.327	-1.726	-1.194	-0.749	-0.344	0.066	0.589	-11.037	-15.369	-14.383	-26.007
ESP	0.040	0.071	0.058	0.055	0.056	0.051	0.040	0.044	0.047	0.046	0.041	0.659	-0.490	0.558	0.178
ETH	2.891	2.705	2.893	2.882	2.814	2.889	2.888	2.866	2.883	2.708	7.944	1.865	-4.631	-2.711	-18.324
FIN	0.040	0.045	0.045	0.044	0.043	0.035	0.042	0.042	0.042	0.041	0.041	0.253	-0.509	0.122	-0.374
FJI	7.783	10.698	9.267	8.698	8.404	8.168	7.987	7.847	7.721	7.596	7.447	19.610	9.157	16.089	3.610
FRA	0.280	0.259	0.288	0.283	0.278	0.284	0.280	0.285	0.285	0.284	0.286	1.801	0.980	1.618	0.925
GBR	0.060	0.070	0.067	0.068	0.066	0.065	0.064	0.059	0.063	0.057	0.062	0.184	-0.853	0.008	-0.659
GHA	2.201	0.876	0.867	0.794	0.634	1.258	1.753	2.172	2.545	2.919	3.491	2.926	-3.092	0.057	-10.149
GMB	2.371	3.095	3.094	3.066	3.086	1.775	2.140	2.099	2.354	2.420	2.449	5.850	-6.201	2.328	-10.034
GRC	-0.260	-0.233	-0.248	-0.262	-0.257	-0.258	-0.259	-0.259	-0.260	-0.262	-0.262	-1.259	-2.277	-1.280	-1.360
GTM	0.780	0.143	0.193	0.399	0.537	0.623	0.693	0.742	0.792	0.837	0.896	1.030	-0.805	0.224	-2.785
GUY	8.413	11.359	8.137	8.295	8.343	8.381	8.400	8.411	8.412	8.409	8.317	14.318	-3.534	9.717	-6.160
HND	5.772	3.990	3.988	0.522	2.271	3.595	4.587	5.340	6.025	6.633	7.457	9.678	0.525	5.587	-8.634
HTI	2.191	-0.157	-0.169	-0.165	-0.157	-0.148	-0.190	4.763	2.215	0.009	-1.625	-6.558	-10.247	-7.018	-8.747
HUN	0.250	0.295	0.272	0.272	0.259	0.255	0.252	0.250	0.247	0.244	0.239	0.598	-1.875	0.230	-1.157
IDN	0.760	0.437	0.577	0.634	0.674	0.707	0.737	0.764	0.787	0.815	0.857	-0.015	-1.297	-0.806	-3.760
IND	2.431	0.637	0.633	0.960	1.385	1.761	2.075	2.383	2.685	3.013	3.512	-0.279	-2.925	-2.168	-9.037
IRL	0.910	0.921	0.913	0.912	0.910	0.909	0.912	0.907	0.906	0.902	0.904	3.020	0.465	2.439	0.257
IRN	-0.060	-1.456	-0.751	-0.516	-0.366	-0.249	-0.154	-0.080	-0.016	0.047	0.135	-3.412	-3.973	-3.786	-5.199
ISL	1.351	1.524	1.387	1.363	1.354	1.349	1.358	1.356	1.338	1.334	1.335	5.249	1.354	4.699	2.632
ISR	-0.600	-0.492	-0.540	-0.563	-0.576	-0.590	-0.592	-0.599	-0.604	-0.604	-0.619	-3.018	-6.808	-3.187	-3.829
ITA	0.210	0.210	0.214	0.217	0.217	0.213	0.212	0.205	0.222	0.203	0.206	1.769	1.033	1.626	1.080
JAM	2.762	2.054	2.424	2.564	2.626	2.675	2.723	2.744	2.762	2.786	2.818	5.053	-2.773	2.325	-7.426
JPN	-0.300	-0.275	-0.286	-0.288	-0.290	-0.292	-0.288	-0.299	-0.303	-0.300	-0.300	-5.946	-8.074	-5.937	-5.902
KEN	4.923	1.362	1.355	1.363	1.319	4.741	4.814	4.891	4.961	5.023	5.135	2.623	-2.595	-0.186	-10.193
KOR	-0.330	0.082	-0.195	-0.260	-0.290	-0.312	-0.323	-0.324	-0.348	-0.360	-0.382	-5.458	-14.595	-5.710	-6.664
LKA	6.823	10.128	8.777	8.141	7.748	7.441	7.192	6.954	6.729	6.486	6.065	9.155	-2.790	6.258	-4.082
MAR	-0.770	-2.148	-1.610	-1.312	-1.110	-0.985	-0.893	-0.797	-0.697	-0.622	-0.532	-3.996	-13.677	-5.344	-10.304
MDG	6.613	1.594	1.603	1.590	1.595	1.603	7.466	6.734	6.067	5.458	4.640	8.968	6.497	7.365	1.476
MEX	0.550	0.369	0.484	0.522	0.545	0.542	0.549	0.556	0.546	0.566	0.570	0.506	-3.678	-0.857	-5.879
MLI	-1.111	-1.177	-1.177	-1.177	-1.217	-1.192	-2.267	-1.644	-1.138	-0.697	-0.064	-3.157	-4.761	-4.041	-7.335
MOZ	7.903	9.902	9.909	9.907	9.900	9.995	7.552	7.494	9.137	10.898	14.164	14.380	0.641	7.896	-13.592
MWI	5.523	1.709	1.714	1.724	1.711	1.716	1.722	5.476	5.608	5.746	6.005	3.057	-1.065	0.360	-9.276
MYS	2.281	1.571	1.922	2.100	2.136	2.181	2.229	2.266	2.301	2.335	2.375	5.159	-3.702	1.808	-9.998
NER	1.261	-0.672	-0.683	-0.667	-0.707	-0.706	-0.698	1.339	1.103	0.941	0.761	-5.209	-6.439	-6.031	-9.095
NGA	-6.184	-0.232	-0.230	-0.220	-0.215	-0.220	-0.215	-0.211	-5.532	-3.332	-0.124	-11.086	-16.043	-13.040	-20.089
NIC	2.261	2.302	-0.239	0.880	1.436	1.749	1.961	2.117	2.318	2.486	2.673	5.559	1.524	4.195	-0.836
NLD	0.400	0.422	0.404	0.403	0.401	0.400	0.398	0.400	0.395	0.389	0.386	1.700	-1.094	1.339	-0.022
NOR	0.520	0.528	0.523	0.511	0.520	0.520	0.524	0.526	0.526	0.525	0.523	2.652	1.624	2.402	1.458
NPL	2.741	2.728	2.755	2.709	2.746	2.756	2.758	2.746	-0.656	0.399	2.250	-3.299	-7.699	-4.743	-10.043
NZL	1.711	1.601	1.676	1.688	1.695	1.708	1.707	1.711	1.708	1.718	1.722	7.065	5.987	6.323	3.544
PAK	2.921	0.791	1.174	1.616	1.936	2.212	2.457	2.707	2.966	3.287	4.059	-1.155	-5.087	-3.460	-11.752
PER	0.610	0.579	0.603	0.604	0.627	0.612	0.613	0.615	0.616	0.612	0.610	0.647	-1.419	-0.012	-2.479
PHL	3.641	4.267	4.009	3.891	3.810	3.750	3.704	3.665	3.633	3.609	3.596	4.907	1.095	2.805	-4.816
PNG	2.461	2.811	2.644	2.576	2.543	2.508	2.483	2.474	2.434	2.404	2.391	6.676	0.688	5.327	0.346
PRT	-0.420	-0.391	-0.408	-0.409	-0.421	-0.420	-0.424	-0.422	-0.426	-0.425	-0.450	-0.998	-2.208	-0.984	-0.931
PRY	1.231	-1.285	-0.760	0.141	0.502	0.783	0.979	1.135	1.283	1.406	1.591	1.149	-1.023	-0.483	-6.458
ROM	1.171	1.732	1.433	1.330	1.274	1.227	1.188	1.158	1.129	1.094	1.046	3.131	1.492	2.571	0.466
RWA	1.871	2.535	2.499	2.415	2.525	2.503	1.005	1.665	2.213	2.927	3.944	4.924	0.663	2.921	-4.359
SEN	2.561	0.427	0.404	2.299	2.385	2.445	2.499	2.546	2.583	2.636	2.726	1.869	-2.413	-0.192	-7.659
SLE	3.932	3.912	3.900	3.893	3.918	3.939	3.915	3.846	3.906	10.655	8.898	7.421	1.219	4.305	-6.750
SLV	0.450	0.097	0.312	0.392	0.414	0.434	0.434	0.453	0.460	0.458	0.486	-0.007	-1.789	-0.674	-3.172
SWE	-0.110	-0.106	-0.107	-0.108	-0.108	-0.108	-0.108	-0.109	-0.109	-0.109	-0.109	0.353	-0.454	0.167	-0.539
SYR	-1.100	1.304	0.082	-0.341	-0.587	-0.766	-0.931	-1.057	-1.174	-1.281	-1.415	-7.143	-10.892	-8.594	-13.911
TCD	0.780	-0.451	-0.482	-0.460	-0.482	-0.468	-0.461	0.762	0.590	0.510	0.294	-6.503	-7.550	-7.006	-8.896
TGO	3.491	0.761	0.739	0.128	1.273	2.154	2.876	3.535	4.151	4.809	5.945	4.910	-1.493	0.837	-13.272
THA	12.397	15.409	14.065	13.614	13.187	12.879	12.646	12.458	12.309	12.195	12.078	18.196	0.102	12.521	-6.692
TUN	-0.170	-0.256	-0.181	-0.172	-0.154	-0.154	-0.161	-0.170	-0.181	-0.205	-0.254	-3.986	-23.924	-4.604	-6.918
TUR	-0.780	-1.794	-1.298	-1.106	-0.987	-0.905	-0.842	-0.794	-0.751	-0.714	-0.666	-5.541	-8.340	-5.894	-7.225
TZA	16.870	5.876	5.865	5.859	5.870	5.868	5.864	16.851	16.703	16.567	16.379	8.882	-0.093	2.891	-17.049
UGA	0.240	0.829	0.837	0.719	0.809	0.793	-1.295	-0.340	0.346	1.091	2.142	3.480	1.799	2.361	-1.787
URY	1.781	1.930	1.835	1.808	1.796	1.789	1.784	1.782	1.781	1.781	1.781	6.304	4.689	5.431	2.174
USA	0.570	0.540	0.554	0.568	0.573	0.566	0.568	0.568	0.570	0.570	0.572	0.000	-0.728	-0.563	-2.676
VEN	-1.040	-2.258	-1.498	-1.304	-1.199	-1.131	-1.083	-1.047	-1.017	-0.992	-0.948	-5.995	-6.672	-6.297	-7.440
ZAF	0.210	0.022	0.089	0.135	0.151	0.206	0.189	0.198	0.198	0.220	0.250	-1.088	-2.399	-1.784	-4.388
ZMB	3.152	0.310	0.298	0.305	0.297	0.331	0.305	2.876	3.162	3.418	3.794	1.705	-2.376	-0.695	-9.321
ZWE	1.261	-0.966	-0.988	-0.963	-0.975	-1.048	-0.067	0.524	0.968	1.373	1.831	-0.112	-5.354	-2.614	-11.573

First, the asymmetry in the import tariff matrix is such that relatively rich countries cannot benefit much from tariff liberalization as they (i) generally impose lower tariffs than poor countries and (ii) especially in the manufacturing sector. Lowering import tariffs in the agricultural sector, on the other hand, would not have significant price effect on welfare under ARC because average consumers in rich countries spend relatively more on manufacturing goods. As captured in Figure 6, average consumers in rich countries do not experience significant changes in their welfare as the gains in those countries vary between -1% and 1%. Developing countries impose higher tariffs in the benchmark year and especially so in the agricultural sector. Hence, they have higher potential for welfare gains because of (i) higher total reduction in import trade barriers and because (ii) consumers in those countries spend relatively larger share of income on food. This is confirmed in Figure 6, where average consumers in poor countries gain relatively more as a result of global elimination of tariffs.

Apart from the wage and price effects there is a second (nominal income) effect that occurs due to the loss of tariff revenues in each country. In Figure 5, I demonstrated that tariff revenues are not negligible for some poor countries where they can constitute to up to 3-5% of total GDP. Accordingly, this implies that an average consumer loses 3-5% of his total nominal income due to the loss of tariff revenues. The results of Experiment 2 suggest that under ARC such loss may be larger than the potential gains from the reduction in prices and/or change in wages for some countries.

In the right panel of Figure 6, I plot the measurement errors from ARC calculated under the scenario of trade liberalization in tariffs. Most errors lie between -3 and 5 percentage points while the welfare gains of average consumers across countries vary between -2% and 9%. In addition to substantial quantitative errors from ARC, there are frequent *qualitative* errors across all deciles. They occur when the welfare gains under ARC and under heterogeneous consumers have different signs such that $\bar{\Delta}_i \times \Delta_{id} < 0$. I use $\square$ to denote them in Figure 6. Though, more prevalent among the poor, qualitative errors occur in all deciles.

It is reassuring that main results of Experiment 1 carry through here as well – the magnitude and the dispersion of the measurement errors from ARC is comparable to the level of welfare gains of average consumers across countries. I also have to note that the results in this section should be viewed as a *lower bound* of how global tariff liberalization policy would affect consumers within and across countries as such policy is likely to incur costs beyond loss of tariff revenues.

7 Conclusion

I have developed a multi-country model of trade with non-homothetic preferences, heterogeneous consumers and multiple sectors with sector-specific trade elasticity parameters. In the model, relatively rich consumers spend higher share of their income on goods produced in sector with higher technological dispersion. Hence, under uniform trade liberalization, consumers in the right tale of the income distribution have higher potential gains from trade. As it turns out, the differences in the welfare gains between different consumers are large such that the gains of an average consumer are no longer a relevant metric, especially in poor countries with high inequality.

Under certain policy scenarios, the welfare predictions for an average consumer differ qualitatively and quantitatively from the prediction under consumer heterogeneity. The qualitative bias is skewed towards the poor and the quantitative bias is substantial at both tails of the income distribution. Predictions under ARC are likely to overstate the gains from trade for the poor and understate them for the rich. Hence, policy evaluations based on ARC may mask true welfare gains for different consumer groups and should be taken with caution. The problem is much more acute in developing countries with low per-capita average income and high income inequality

Admittedly, one of the caveats of the model is the assumption of exogenous and stationary distribution of labor. However, in a multi-country framework endogenous accumulation and/or non-stationary endowment distribution would complicate the model significantly. My approach provides quantitative predictions with regard to income inequality and consumer-specific welfare gains that should be a good first-order approximation of a model with endogenous endowment accumulation. I leave this for future research.

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Appendix

7.1 Data

The reference year for all data is 1996. Trade data are from Feenstra, Lipsey, and Bowen (1997). I aggregate industry-level trade flows into manufacturing and agriculture trade. Trade deficit constants D_{ai} and D_{mi} are calculated as total imports minus total exports in the respective sector. Data on total GDP, average real GDP per capita are from the World Bank's World Development Indicators (WDI) database. The data on sectoral production are from UNIDO. In case these data were unavailable I imputed them from the World Bank's WDI data on total value added. The data on the aggregate expenditure shares and prices[23] are from the Penn World Tables Benchmark 1996 data. The input-output tables are from the OECD's Structural Analysis (STAN) database. Distance and adjacency variables are from the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII). Tariffs are simple averages taken across all available product categories at HS2 classification for each sector and bilateral pair. The data are from the Market Access Map Database (MacMap) which provides tariff data at HS2 sectoral level. I calculate the average import tariff using the classification identical to the one used for the aggregation of the trade data. Whenever, tariff data were missing in the MacMap database I used closest (in terms of the reported year) available tariff data provided by Mayer, Paillacar and Zignago (2008) and/or the World Bank. For bilateral pairs where tariff data were not available I used importer's average applied rate. Data on the distribution of income are from UN-WIDER World Income Inequality Database (WIID). If data for certain deciles were missing, they were imputed from Klaus and Squire (1996) and Milanovic and Yitzhaki (2001).

7.2 Solution: counterfactual experiments

Dekle, Eaton and Kortum (2007) proposed a way to solve for counterfactual outcomes in Ricardian models by expressing the variables in relative changes and using real data. The advantage of their solution algorithm is the fact that one does not have to estimate unobservable trade cost and technology primitives of the model. However, relative to models with homothetic preferences using Dekle, Eaton and Kortum (2007) approach in a model with non-homothetic preferences is more demanding in terms of the data requirements. Under homothetic preferences, the benchmark level of prices and income are not necessary to conduct counterfactual exercises. In such models, a counterfactual equilibrium would only depend on relative changes in prices and income as the share of income spent on tradables stays constant. Non-homothetic preference structure requires additional data on prices and income as they are required to compute relative consumption shares in the benchmark and coun-

[23] Expenditure and price data were not available for all countries in the sample. If missing, the observations were imputed using average real income and price regressions.

terfactual equilibria. However, with such data[24] at hand, relative changes in prices and wages are also sufficient to determine counterfactual equilibrium trade flows and consumer welfare.

Next, I provide details on the solution of the first experiment. The solution of the second experiment is computationally identical. The procedure is iterative and is based on the contraction mapping algorithm as in Alvarez and Lucas (2007). Start with the multilateral trade balance condition to solve for the change in wages $\widehat{w}_i$:

$$\widehat{w}_i Y_i \sum_{j=1}^{J} \left(S'_{mi} x'_{m,ij} + S'_{ai} x'_{a,ij} \right) + D'_{mi} + D'_{ai} = \sum_{j=1}^{J} \widehat{w}_j Y_j \left(S'_{mj} x'_{m,ji} + S'_{aj} x'_{a,ji} \right), \tag{7.1}$$

where Y_i and Y_j are the data on GDP. With the solution of $\widehat{w}_i$ I can calculate counterfactual final demands for n, m and a:

$$N'_i = \sum_{d=1}^{10} \left\{ \mathbf{1}_{\widehat{w}_i Y_{id} > W'^*_i} \right\} \alpha\beta \left(\widehat{w}_i Y_{id} - W'^*_i \right); \tag{7.2}$$

$$M'_i = \sum_{d=1}^{10} \left\{ \mathbf{1}_{\widehat{w}_i Y_{id} > W'^*_i} \right\} \alpha(1-\beta) \left(\widehat{w}_i Y_{id} - W'^*_i \right); \tag{7.3}$$

$$A'_i = \sum_{d=1}^{10} \left\{ \mathbf{1}_{\widehat{w}_i Y_{id} > W'^*_i} \right\} \widehat{w}_i Y_{id}(1-\alpha) + \alpha W'^*_i + \left\{ \mathbf{1}_{\widehat{w}_i Y_{id} \leq W'^*_i} \right\} \widehat{w}_i Y_{id}, \tag{7.4}$$

where Y_{id} are observable data on income distribution and $W'^*_i = \frac{\mu(1-\alpha)}{\alpha\beta} \left(\frac{\beta}{1-\beta} \frac{p'_{mi}}{p'_{ni}} \right)^{1-\beta}$. Having obtained N'_i, M'_i and A'_i I calculate country level spending on n, m and a from the following equation:

$$\underbrace{\begin{pmatrix} S'_{ni} \widehat{w} Y_i \\ S'_{mi} \widehat{w} Y_i \\ S'_{ai} \widehat{w} Y_i \end{pmatrix}}_{\text{Sectoral Absorption}} = \underbrace{\begin{pmatrix} (1-\phi)\varrho & (1-\phi)(1-\varrho) & 0 \\ (1-\xi)\zeta & (1-\xi)(1-\zeta) & 0 \\ (1-\gamma)\epsilon & (1-\gamma)\rho & (1-\gamma)(1-\epsilon-\rho) \end{pmatrix} \begin{pmatrix} S'_{ni} \widehat{w} Y_i \\ S'_{mi} \widehat{w} Y_i - D'_{mi} \\ S'_{ai} \widehat{w} Y_i - D'_{ai} \end{pmatrix}}_{\text{Intermediate Demand}} + \underbrace{\begin{pmatrix} N'_i \\ M'_i \\ A'_i \end{pmatrix}}_{\text{Final Demand}}. \tag{7.5}$$

Exogenous trade imbalances are kept constant relative to the world GDP such that:

$$D'_{mi} = \frac{\sum_\ell \widehat{w}_\ell Y_\ell}{\sum_\ell Y_\ell} D_{mi} \quad D'_{ai} = \frac{\sum_\ell \widehat{w}_\ell Y_\ell}{\sum_\ell Y_\ell} D_{ai} \tag{7.6}$$

[24] The data on benchmark prices are from Penn World Tables Benchmark 1996 data. Benchmark wages of each decile were computed using data on average real income and income inequality.

The counterfactual price vector is calculated as follows:

$$p'_{mi} = p_{mi}\left(\sum_{\ell}^{N} x_{m,i\ell}(\widehat{\kappa}_{m\ell}\widehat{t}_{m,i\ell})^{-\theta_m}\right)^{-\frac{1}{\theta_t}}; \tag{7.7}$$

$$p'_{ai} = p_{ai}\left(\sum_{\ell}^{N} x_{a,i\ell}(\widehat{\kappa}_{a\ell}\widehat{t}_{a,i\ell})^{-\theta_a}\right)^{-\frac{1}{\theta_a}}; \tag{7.8}$$

$$p'_{ni} = p_{ni}\widehat{w}^{\phi}(\widehat{p}_{ni}^{\varrho}\widehat{p}_{mi}^{1-\varrho})^{1-\phi}. \tag{7.9}$$

The counterfactual trade flows are calculated as follows:

$$x'_{m,ij} = \frac{x_{m,in}(\widehat{\kappa}_{mj}\widehat{\tau}_{m,ij})^{-\theta_m}}{\sum_{\ell}^{N} x_{m,i\ell}(\widehat{\kappa}_{m\ell}\widehat{t}_{m,i\ell})^{-\theta_m}}; \quad x'_{a,ij} = \frac{x_{a,ij}(\widehat{\kappa}_{aj}\widehat{\tau}_{a,ij})^{-\theta_a}}{\sum_{\ell}^{N} x_{a,i\ell}(\widehat{\kappa}_{a\ell}\widehat{t}_{a,i\ell})^{-\theta_a}}, \tag{7.10}$$

where $x_{m,ij}$ and $x_{a,ij}$ are observable data on trade flows in shares. Finally, change in the average variable costs are:

$$\widehat{\kappa}_{mi} = \widehat{w}_i^{\xi}\left(\widehat{p}_{ni}^{\zeta}\widehat{p}_{mi}^{1-\zeta}\right)^{1-\xi}; \quad \widehat{\kappa}_{ai} = \widehat{w}_i^{\gamma}\left(\widehat{p}_{ni}^{\epsilon}\widehat{p}_{mi}^{\rho}\widehat{p}_{ai}^{1-\epsilon-\rho}\right)^{1-\gamma}. \tag{7.11}$$

These two equation close the system. Overall, equations in (7.1)-(7.11) formulate a $\{92\times 15 + 92\times 92\times 2\}$ system of equations that can be solved for $\{92\times 15 + 92\times 92\times 2\}$ unknowns. The numeraire is $w_{USA} = w'_{USA} = 1$.