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 5 (11) 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 -15 and 4 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 a majority of relatively rich and educated individuals seem to favour lowering barriers to trade, up to 80% of the poor do not feel helped by globalisation 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 liberalisation 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-homotheticity of preferences and sector-specific trade elasticity parameters. In the model, consumers are heterogeneous in two ways. First, they differ in terms of their labour endowment which can be interpreted as heterogeneity in capital, abilities and/or skills endowment. Second, consumers are also heterogeneous in terms of their marginal propensity to consume necessities versus luxuries. I argue that the conventional *assumption of a representative consumer* (ARC) completely ignores these issues which leads to significant quantitative and qualitative deviations of the welfare gains calculated under ARC from consumer-specific gains. This result offers potentially important policy implications since many studies targeting policy makers and trade negotiators are based on ARC and homothetic preferences. For example, recent independent study carried out for the European Comission that calculated potential welfare gains from the Transatlantic Trade and Investment Partnership is based on ARC and homotheticity.[3]

[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 labour adjustment model and estimate how trade liberalisation 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] Full study can be accessed at http://ec.europa.eu/trade/policy/in-focus/ttip/resources/.

I calibrate the model to data from 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, (ii) rich consumers spend a larger share of their total income on manufacturing goods and services, and that (iii) the rich have relatively higher propensity to consume manufacturing goods and services.[4] These 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 liberalisation experiments and demonstrate that the welfare gains from trade largely differ both qualitatively and quantitatively across individuals.

In the first experiment, I assume 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 5 percentage points and underestimates the gains of the rich by up to 11 percentage points. Such dispersion is extremely large considering that the welfare gain estimates under ARC lie between 1 and 20%. In the second experiment, I globally abolish import tariffs such that the trade liberalisation 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 -15 and 4 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 especially by the poor countries. I show that the former 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 trade liberalisation cost is not innocuous. I also argue that the results of these two experiments are robust to various alternative specifications and extensions.

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 two counterfactual trade liberalisation experiments to assess the validity of the predictions under ARC and calculate consumer-specific welfare gains in Section 6. In Section 7, I discuss the robustness of the main results to various extensions and alternative modelling structures of the production

[4] 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).

and consumption sides. The final section offers a brief conclusion.

2 Related Literature

Until recently, much of the theoretical and empirical work assumed homothetic preferences and homogenous consumers.[5]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 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 skill premium and income elasticity of demand.[6] 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.

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 these differences largely stem from two sources: consumers differ in their endowment of labour force and their relative preferences for manufacturing goods and services versus

[5]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).

[6]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.

[7]Admittedly, Fieler (2011) and Caron, Fally and Markusen (2012) briefly discuss possible extensions of their models to include consumer heterogeneity (see Sections 5.1 and 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.

agricultural goods. The latter form of heterogeneity is consistent with Di Comite, Thisse and Vandenbussche (forthcoming) who show in a different context that preference heterogeneity is important for explaining trade flows. Overall, ARC either 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 liberalisation is governed by the trade elasticity parameter (Frechèt dispersion parameter in Eaton-Kortum-type models). Depending on this parameter, sectors would experience heterogeneous changes in prices. Since rich consumers spend disproportionately larger share of their income on manufacturing 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 liberalisation would offer higher benefits to the rich.[8]

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, 2011; Ossa, 2011). Amiti and Konings (2007) show that reduction in tariffs on intermediate inputs offers substantial gains in productivity. The model here is consistent with these findings, trade liberalisation 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.

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.[9]Burstein and Vogel (2012) and Parro (2013) formulate Ricardian models and examine the effect of trade on income inequality through skill premium. In contrast to

[8]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.

[9]For example, Davis and Harrigan (2011) introduce labour market frictions into a variant of Melitz (2003) model and show that while trade liberalisation raises *average* wage, it negatively impacts workers that had relatively high wages in pre-trade equilibrium.

these two strands of the literature, the model here emphasises the demand channel and shows that even when relative factor rewards do not change, workers experience heterogeneous effects of trade liberalisation. 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 liberalisation. In Section 7, I show that consumer heterogeneity and non-homotheticity are essential for calculating the welfare gains from trade in the presence of Stolper-Samuelson-type effects.

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 USA 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 $i = (1, \ldots, J)$ is endowed with L_i units of labour which is inelastically supplied to a measure of heterogeneous firms in the agricultural, manufacturing and non-tradable sectors.[10]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.[11]Labour is assumed to be completely mobile across sectors but not countries.

I introduce two types of consumer heterogeneity. First, in the spirit of Mayer (1984) I assume that households own different shares of total labour. Households of type $d \in \mathcal{D}$ own ℓ_{id} share of labour force (and aggregate income) such that $\int_{h \in \mathcal{D}} \ell_{ih} dh = L_i$.[12]Second, consumers also

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

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

[12] In the quantitaive analysis, I use deciles to approximate the distribution of labour endowments, simply because no data are available on a more disaggregated level, hence it is convenient to use d to denote consumer type. There are many ways to interpret heterogeneity across households in terms of their labour 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.

differ in their marginal propensity to consume manufacturing goods and services relative to agricultural goods. I formulate a stochastic relationship between marginal propensity to consume and consumer's income which ensures that on average the rich tend to value consumption of the manufacturing goods and services relatively more than the poor. The relationship, however, is not deterministic and allows for certain degree of heterogeneity in tastes even within each income class.

The two types of heterogeneity are combined with a non-homothetic preference structure such that changes in income and/or prices (e.g. due to a trade liberalisation) have heterogeneous effects on the consumption patterns across households and countries. Due to non-homotheticity, each consumer spends fixed amount of income (common to all consumers) on subsistence good before consuming manufacturing goods and services. However, once consumers have enough income to consume all goods, they differ in their consumption behaviour.[13]

3.1 Households

Households of type $d \in \mathcal{D}$ in country i maximise consumption of non-tradable good, n_i, tradable manufacturing good, m_i, and tradable agricultural good, a_i, according to the following nested Stone-Geary-type utility function:

$$U_{id}(n_{id}, m_{id}, a_{id}) = \left(n_{id}^{\beta} m_{id}^{1-\beta} + \frac{\mu \alpha_{id}}{1 - \alpha_{id}} \right)^{\alpha_{id}} {a_{id}}^{1-\alpha_{id}} \tag{3.1}$$

such that $y_{id} = n_{id}p_{ni} + m_{id}p_{mi} + a_{id}p_{ai}$, where p_{ni}, p_{mi} and p_{ai} are prices of the non-tradable, manufacturing, and agricultural goods, respectively, and $y_{id} = w_i \ell_{id}$ is the total income of the household d from his labour endowment, ℓ_{id}. The parameters are restricted such that β and α_{id} are inside the unit interval. The latter parameter reflects marginal propensity to consume n_{id} and m_{id} relative to a_{id}. I assume that α_{id} and y_{id} are not independent and have a joint distribution function $F_{\alpha y}(\alpha_{id}, y_{id})$.

The utility function in (3.1) has two important properties relative to the literature. First, it is non-homothetic which ensures that *before* consuming non-tradable and manufacturing goods each consumer must spend certain amount of her income on food. The amount of

[13] 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: 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.

food required for subsistence is common to all consumers and does not depend on income or consumer-specific preference parameters. This is the first margin of the link between income inequality and international trade. Consumers that do not have sufficiently high income will spend all their income on food. Hence, in poor countries income distribution has central role in shaping import demand via the aggregate share of consumers that can afford buying goods beyond a_i.

Second, parameter α_{id} is heterogeneous across consumers. This parameter can be interpreted as marginal propensity to consume manufacturing goods and services relative to agricultural goods. It seems intuitive to assume (evidence in support of this assumption will be provided) that rich consumers tend to have a higher α_{id}. I specify this relationship via a joint distribution function $F_{\alpha y}(\alpha_{id}, y_{id})$ such that the relationship is not deterministic and may be subject to stochastic consumer-specific taste shocks. This specification of preferences is motivated by recent theoretical and empirical literature on the aggregation properties of consumer demand. For example, Cherchye, Crawford, De Rock and Vermeulen (2013) use revealed preference approach and microdata to show that although individual consumption behaviour can be rationalised by the class of Gorman Polar Form preferences (as in (3.1) for each d), aggregate demand cannot be captured by a single representative consumer due to heterogeneity in marginal utility of income (analogous to heterogeneity in α_{id}). This heterogeneity in tastes constitutes the second margin of the link between income inequality and aggregate demand as consumers differ in their expenditure shares of n_i, m_i and a_i.[14]

I next turn to characterising demands for consumer d in country i. For brevity, define the cut-off level of income in i as $c_i = \mu(1-\beta)^{\beta-1}\beta^{-\beta}p_{mi}^{1-\beta}p_{ni}^{\beta}$, then whenever $y_{id} > c_i$ consumer d has the following demands:

$$n_{id} = \frac{\alpha_{id}\beta(y_{id} - c_i)}{p_{ni}}; \quad m_{id} = \frac{\alpha_{id}(1-\beta)(y_{id} - c_i)}{p_{mi}}; \quad a_{id} = \frac{(1-\alpha_{id})y_{id} + \alpha_{id}c_i}{p_{ai}}. \tag{3.2}$$

Otherwise, she buys zero manufacturing and non-tradable goods and spends all her income on food. Two important properties of the utility function discussed above translate into the demand equations: subsistence condition c_i is common to all consumers in i; marginal propensity to consume n_i and m_i versus a_i is heterogeneous across consumers and depends on consumer-specific α_{id}.

Let Υ_{ni}, Υ_{mi} and Υ_{ai} denote country-level expenditure shares on non-tradables, manufacturing and agricultural goods, respectively. Country i with a measure of different consumer

[14] These two properties of the utility function explain empirically established link between international trade and income inequality. For example, see Goldberg and Pavcnik 2004, 2007; Dalgin, Trindade and Mitra, 2008; Harrison, McLaren and McMillan, 2010; Bekkers, Francois and Manchin, 2012.

types $\mathcal{D}$ and a measure of total labour L_i has the following expenditure shares:

$$\Upsilon_{ai} \equiv \frac{L_i E[p_{ai} a_{id}]}{L_i w_i} = \pi_i \left(\frac{E\left[(1-\alpha_{id}) y_{id}\right]}{w_i} + \frac{c_i E[\alpha_{id}]}{w_i} \right) + (1-\pi_i) \frac{E[y_{id}]}{w_i}; \tag{3.3}$$

$$\Upsilon_{ni} = \beta(1-\Upsilon_{ai}); \quad \Upsilon_{mi} = (1-\beta)(1-\Upsilon_{ai}), \tag{3.4}$$

where $\pi_i = \Pr(y_{id} > c_i)$ is a probability that a randomly drawn consumer in i has income higher than the cut-off level. This variable can be interpreted as a share of population in i that consume output of all three sectors. I use $E[\cdot]$ to denote expectation operator. In (3.3), π_i and $E[y_{id}]$ can be calculated using within-country distribution of labour endowments ℓ_{id} and average wage w_i.

To calculate the expectation term $E[(1-\alpha_{id})y_{id}]$, one needs to know joint distribution of α_{id} and y_{id}. To ensure that the relationship between the two is consistent and monotone across all countries, I assume that the joint distribution $F_{\alpha y}(\alpha_{id}, y_{id})$ is global. Since I have no priors regarding the marginal distribution of the preference parameters α_{id}, except for the clear bounds between zero and unity, I assume that α_{id} are distributed uniform between $\underline{\alpha} \geq 0$ and $\overline{\alpha} \leq 1$.[15] On the other hand, the marginal distribution of y_{id} in the world is known to be well approximated by a Pareto distribution. I assume that y_{id} follows Pareto with scale and shape parameters $y_{wm} = \min_{i,d}\{y_{id}\}$ and ψ_w, respectively. The two marginal distributions are as follows:

$$F_\alpha(\alpha_{id}) = \frac{\alpha_{id} - \underline{\alpha}}{\overline{\alpha} - \underline{\alpha}} \text{ for } \underline{\alpha} \leq \alpha_{id} \leq \overline{\alpha}; \quad F_y(y_{id}) = 1 - \left(\frac{y_{wm}}{y_{id}}\right)^{\psi_w} \text{ for } \psi_w > 0, y_{wm} > 0. \tag{3.5}$$

I use these two marginal distributions to derive joint distribution of y_{id} and α_{id} using Sklar's Theorem that states that any two marginal distributions and a copula can be used to generate a multivariate joint distribution function. I piece together $F_\alpha(\alpha_{id})$ and $F_y(y_{id})$ into a joint distribution function $F_{\alpha y}(\alpha_{id}, y_{id})$ via a bivariate copula $C : [0,1]^2 \to [0,1]$:[16]

$$F_{\alpha y}(\alpha_{id}, y_{id}) = C\left(F_\alpha(\alpha_{id}), F_y(y_{id}), \rho\right), \tag{3.6}$$

where ρ is a parameter that measures correlation between α_{id} and y_{id}. I employ a copula developed in Frank (1979) because of its symmetry and relative flexibility.[17] Then, the joint

[15] I have also experimented with alternative functional forms of $F_\alpha(\alpha_{id})$ (e.g. bounded Pareto) and the results are robust to such changes.

[16] For general discussion of copulas and their properties see Nelsen (2006) and Triverdi and Zimmer (2007).

[17] As long as C is flexible in terms of capturing correlation between y_{id} and α_{id} the results are not sensitive to the exact choice of copula. The results are robust to choosing a different C (e.g. Gumbel, Gaussian). However, copulas that are unable to capture strong dependance (e.g. FGM copula) would perform poorer.

distribution function can be stated as follows:

$$F_{\alpha y}(\alpha_{id}, y_{id}) = \rho^{-1} \ln \left(1 + \frac{(e^{-\rho F_y(y_{id})} - 1)(e^{-\rho F_\alpha(\alpha_{id})} - 1)}{e^{-\rho} - 1} \right). \tag{3.7}$$

For positive values of ρ, larger ρ implies higher correlation between α_{id} and y_{id} and vice versa. To illustrate this, I conduct 10,000 draws from the joint distribution in (3.7) using the inverse distribution function method described in Nelsen (2006) and plot the results in Figure 1 for $\rho = 5$ (left panel) and $\rho = 20$ (right panel).

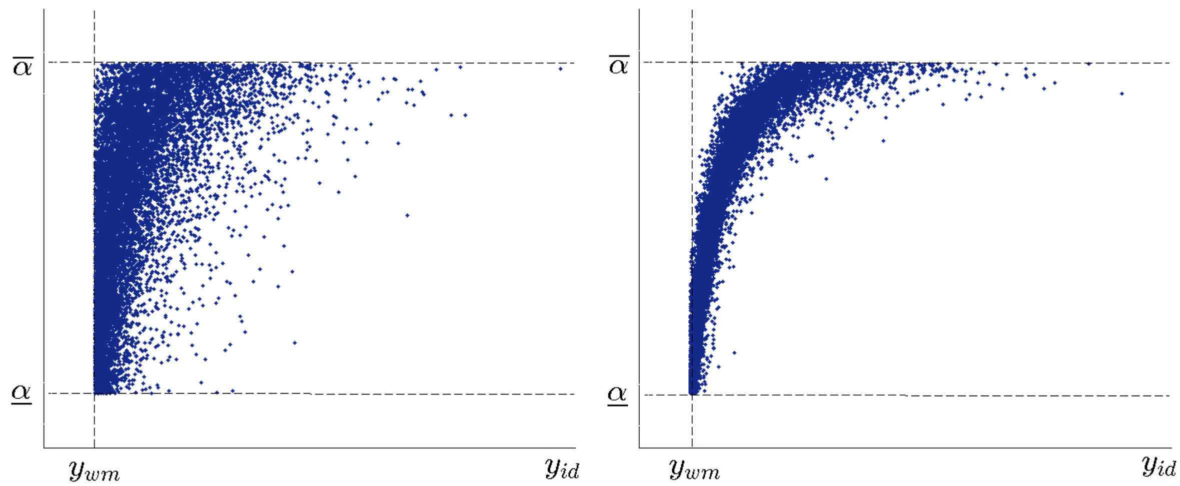

Figure 1: 10,000 DRAWS FROM JOINT $F_{\alpha y}(y_{id}, \alpha_{id})$ WITH $\rho = 5$ (LEFT PANEL) AND $\rho = 20$ (RIGHT PANEL)

Joint distribution function in (3.7) allows evaluating $E[(1-\alpha_{id})y_{id}]$ and calculating expenditure shares Υ_{ai}, Υ_{ni} and Υ_{mi}. Though there is no closed form solution for $E[(1-\alpha_{id})y_{id}]$ it is possible to solve it numerically. I discuss the solution and calibration algorithms in more detail in Section 4.

3.2 Heterogeneity in the 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 liberalisation consumers experience proportional changes in their nominal incomes. This allows me to quantify differences in welfare gains across consumers that accrue purely to asymmetric changes in relative prices. 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 (3.2):

$$V(\alpha_{id}, y_{id}, p_{ni}, p_{mi}, p_{ai}) = \left(\frac{B\alpha_{id}(y_{id} - c_i)}{p_{ni}^{\beta} p_{mi}^{1-\beta}} + \frac{\mu\alpha_{id}}{1-\alpha_{id}}\right)^{\alpha_{id}} \left(\frac{(1-\alpha_{id})y_{id} + \alpha_{id}c_i}{p_{ai}}\right)^{1-\alpha_{id}} \quad \text{if } y_{id} > c_i. \tag{3.8}$$

where $B = (1-\beta)^{1-\beta}\beta^{\beta}$. For brevity, here I assume that all consumers have income larger than the cut-off level. Under a hypothetical trade liberalisation, consumers in i will face a different (endogenously determined) wage rate, w_i', and a new price vector, $\{p_{ni}', p_{mi}', p_{ai}'\}$. To measure changes in welfare, I employ the concept of *equivalent variation*,[18] ev_{id}, defined as the additional income (normalised by the initial income) at pre-trade liberalisation prices $\{p_{ni}, p_{mi}, p_{ai}\}$ necessary to make consumer d in country i indifferent between pre- and post-liberalisation equilibria:

$$V(\alpha_{id}, w_i\ell_{id}(1 + ev_{id}), p_{ni}, p_{mi}, p_{ai}) = V(\alpha_{id}, w_i'\ell_{id}, p_{ni}', p_{mi}', p_{ai}'). \tag{3.9}$$

Let me use $\widehat{b}$ to denote relative change in an arbitrary variable b due to trade liberalisation. Because rich consumers care relatively more about manufacturing goods and services (captured by higher income plus non-homotheticity and higher α_{id}) their gains from trade are larger if $(\widehat{p}_{ni})^{\beta}(\widehat{p}_{mi})^{1-\beta} < \widehat{p}_{ai}$. The reverse is true whenever $(\widehat{p}_{ni})^{\beta}(\widehat{p}_{mi})^{1-\beta} > \widehat{p}_{ai}$ i.e. the poor benefit from trade relatively more. In the left panel of Figure 2, I plot the welfare gains for different values of y_{id} and α_{id} for $(\widehat{p}_{ni})^{\beta}(\widehat{p}_{mi})^{1-\beta} = 0.9$ and $\widehat{p}_{ai} = 1$, and $\widehat{y}_{id} = 1$. The numerical exercise confirms the intuition – under relatively higher decrease in prices of m_i and n_i – consumers with higher income and preferences for manufacturing goods and services benefit relatively more. The right panel in Figure 2 captures the opposite effect. Here, I set $\widehat{p}_{ai} = 0.9$ and $(\widehat{p}_{ni})^{\beta}(\widehat{p}_{mi})^{1-\beta} = 1$ while still keeping income constant $\widehat{y}_{id} = 1$. As the price of agricultural goods now decreases relatively more, the welfare gains from trade are larger for consumers with lower y_{id} and α_{id}.

Hence, whenever trade liberalisation entails asymmetric price effects, the welfare gains from trade will depend on the initial level of income and the preference parameter α_{id}. As it turns out, due to the production structure in the global economy the asymmetry in changes in prices generally favours consumers with higher y_{id} and α_{id} such that under equivalent reduction in trade costs prices of manufacturing goods and services decrease relatively more. I next turn to describing the production structure of the economy.

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

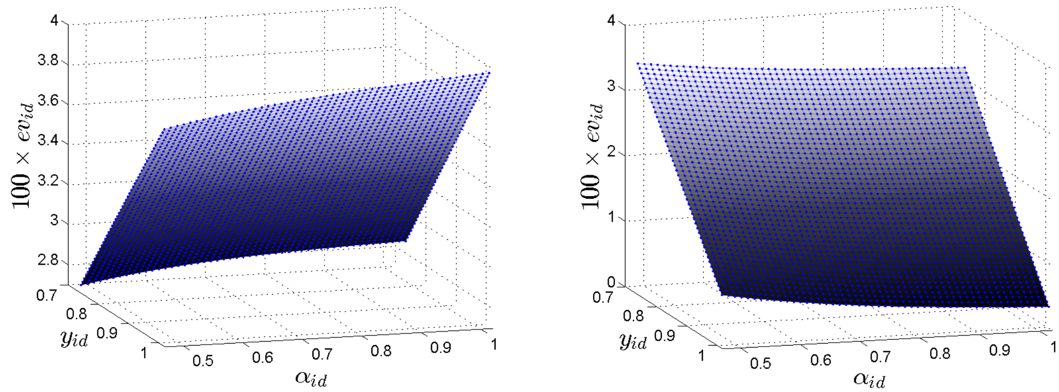

Figure 2: Heterogeneity in the welfare gains from trade

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.[19]This allows me to provide clear quantitative predictions in the counterfactual section that have straightforward interpretation relative to the benchmark data. The main results, however, are robust to alternative specification of production and competition. In Section 7, I discuss alternative production structures such as in Melitz (2003).

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, 2011).[20]

Manufacturing sector

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

[19]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).

[20]Consistent with the literature and the OECD classification I classify industries into 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.

according to:

$$F_{mi}(z_{mi}) = \exp\left(-\lambda_{mi} {z_{mi}}^{-\theta_m}\right), \tag{3.10}$$

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

$$m_i(q) = z_{mi}(q) l_i(q)^{\xi} \left(n_i(q)^{\zeta} m_i(q)^{1-\zeta}\right)^{1-\xi}, \tag{3.11}$$

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:

$$\kappa_{mi} = \Gamma_m {\lambda_{mi}}^{-\frac{1}{\theta_m}} w_i^{\xi} \left(p_{ni}^{\zeta} p_{mi}^{1-\zeta}\right)^{1-\xi}, \tag{3.12}$$

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

$$p_{mi} = \left(\sum_{h}^{J} (\kappa_{mh} \tau_{m,ih} t_{m,ih})^{-\theta_m}\right)^{-\frac{1}{\theta_m}}. \tag{3.13}$$

Agricultural sector

Each firm in the agricultural sector has a total factor productivity parameter drawn from a country-specific productivity distribution:[21]

$$F_{ai}(z_{ai}) = \exp\left(-\lambda_{ai} {z_{ai}}^{-\theta_a}\right). \tag{3.14}$$

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

$$a_i(g) = z_{ai}(g) l_i(g)^{\gamma} \left(n_i(g)^{\epsilon} m_i(g)^{\varphi} a_i(g)^{1-\epsilon-\varphi}\right)^{1-\gamma}. \tag{3.15}$$

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.[22]This modeling choice is consistent with the input-output data on

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

[22]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.

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, κ_{aj}, iceberg trade costs specific to that sector, $\tau_{a,ij}$, and import tariff, $t_{a,ij}$:

$$p_{ai} = \left(\sum_{h}^{J} (\kappa_{ah} \tau_{a,ih} t_{a,ih})^{-\theta_a} \right)^{-\frac{1}{\theta_a}}. \tag{3.16}$$

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:

$$n_i = l(n)_i^{\phi} \left(n_i(n)^{\varrho} m_i(n)^{1-\varrho} \right)^{1-\phi}, \tag{3.17}$$

accordingly the price of the non-tradable good is:

$$p_{ni} = \Gamma_n w_i^{\phi} (p_{ni}^{\varrho} p_{mi}^{1-\varrho})^{1-\phi}, \tag{3.18}$$

where Γ_n is a sector-specific constant.[23]

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 the realisation 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:

$$X_{m,ij} = x_{m,ij} S_{mi} (L_i w_i), \quad \text{and} \quad X_{a,ij} = x_{a,ij} S_{ai} (L_i w_i), \tag{3.19}$$

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 (since 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

[23] 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.

manufacturing and agricultural goods, respectively.

$$x_{m,ij} = \frac{(\kappa_{mj}\tau_{m,ij}t_{m,ij})^{-\theta_m}}{\sum_h^J(\kappa_{mh}\tau_{m,ih}t_{m,ih})^{-\theta_m}}, \quad \text{and} \quad x_{a,ij} = \frac{(\kappa_{aj}\tau_{a,ij}t_{a,ij})^{-\theta_a}}{\sum_h^J(\kappa_{ah}\tau_{a,ih}t_{a,ih})^{-\theta_a}} \tag{3.20}$$

An important difference between the models based on homothetic demand structures and the model here is that the import 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, S_{ni}, S_{mi} and S_{ai} must be calculated as the sum of the consumers' and producers' demands for non-tradable, manufacturing and agricultural goods, respectively.

Total consumers' demands are from (3.3)-(3.4). 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:

$$\underbrace{\begin{pmatrix} S_{ni}(L_iw_i) \\ S_{mi}(L_iw_i) \\ S_{ai}(L_iw_i) \end{pmatrix}}_{\text{Sectoral Absorption}} = \underbrace{\begin{pmatrix} (1-\phi)\varrho & (1-\phi)(1-\varrho) & 0 \\ (1-\xi)\zeta & (1-\xi)(1-\zeta) & 0 \\ (1-\gamma)\epsilon & (1-\gamma)\varphi & (1-\gamma)(1-\epsilon-\varphi) \end{pmatrix} \begin{pmatrix} S_{ni}(L_iw_i) \\ S_{mi}(L_iw_i) - D_{mi} \\ S_{ai}(L_iw_i) - D_{ai} \end{pmatrix}}_{\text{Intermediate Demand}} + \underbrace{\begin{pmatrix} \Upsilon_{in}(L_iw_i) \\ \Upsilon_{im}(L_iw_i) \\ \Upsilon_{ia}(L_iw_i) \end{pmatrix}}_{\text{Final Demand}} \tag{3.21}$$

With observations on L_iw_i (which is equivalent to GDP) in 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}:

$$L_iw_i\sum_{j=1}^{N}\left(S_{mi}x_{m,ij} + S_{ai}x_{a,ij}\right) + D_{mi} + D_{ai} = \sum_{j=1}^{N} L_jw_j\left(S_{mj}x_{m,ji} + S_{aj}x_{a,ji}\right). \tag{3.22}$$

Closing the model in this way is in the spirit of Dekle, Eaton and Kortum (2007).[24]

In contrast to the models with homothetic preferences and/or homogeneous consumers, here

[24] 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 normalise all income values such that the average per-capita income in the USA is unity throughout this paper.

both average per-capita income and income distribution 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, income distribution (captured by the distribution of ℓ_{id}) and international trade flows. Second, depending on within-country distribution of the labour 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 liberalisation leads to heterogeneous welfare effects.

4 Calibration

I calibrate the model to 92 countries in the world for the reference year 1996.[25]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 and the data sources 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. Notice that β is constant across consumers, hence, it is possible to recover β from the ratio of total spending on manufacturing to services:

$$\frac{\beta}{1-\beta} = \frac{1}{J}\sum_{i=1}^{J}\frac{\Upsilon_{ni}}{\Upsilon_{mi}} \tag{4.1}$$

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

Next, I turn to estimation of non-homotheticity parameter, μ, consumer-specific parameters, α_{id}, and the correlation parameter, ρ. For tractability, I assume that each country is populated by ten different households. This assumption allows using data on income deciles to estimate μ and ρ via the simulated method of moments. In Section 3.1, I assumed that y_{id} and α_{id} are distributed according to the joint distribution function $F_{\alpha y}(\alpha_{id}, y_{id})$ with the

[25]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.

following marginal distributions of y_{id} and α_{id}:

$$y_{id} \sim \text{Pareto}\left(\min_{i,d}\{y_{id}\}, \psi_w\right) \text{ and } \alpha_{id} \sim \text{Uniform}(\underline{\alpha}, \overline{\alpha}). \tag{4.2}$$

I observe y_{id} in the data as decile-specific nominal income and treat them as realisation of random variable drawn from the Pareto distribution in (4.2). The scale parameter of the distribution is set to the minimum across all observed countries and deciles and the shape parameter ψ_w is set to 1.29 which corresponds to the world Gini coefficient of 0.64 reported in Sala-i-Martin (2006). Since irrespective of i, α_{id} is allowed to vary between zero and unity, I set $\underline{\alpha} = 0$ and $\overline{\alpha} = 1$.

Parameters ψ_w, $\underline{\alpha}$ and $\overline{\alpha}$, and the data on y_{id} allow me to use simulated method of moments to estimate ρ and μ in the following way. First, given value of ρ, I draw a vector of α_{id}'s using joint distribution function in (3.7) conditional on the observed outcomes of y_{id}. Next, given μ, I calculate prediction for the aggregate share that country i spends on food as in (3.3). I repeat this exercise for different values of ρ and μ until the difference between the prediction and the data is minimized. Formally, I obtain predictions ρ and μ as follows:

$$(\hat{\rho}, \hat{\mu}) = \arg\min_{\rho,\mu} \left\{ \sum_{i=1}^{N} \left[\ln \Upsilon_{ai} - \ln \Upsilon_{ai}(\rho, \mu)\right]^2 \right\}, \tag{4.3}$$

where Υ_{ai}'s are observed in the data. Since I am dealing with a finite number of households in each country the estimates of ρ and μ will depend on realization of α_{id}. To avoid this bias, I simulate α_{ih} and solve for $\hat{\rho}$ and $\hat{\mu}$ 100, 1,000 and 10,000 times (Table 1).

Table 1: Parameters of the Utility Function

Number of Draws	$\hat{\mu}$	std.error	$\hat{\rho}$	std.error
100	0.009	0.000	13.649	0.149
1,000	0.009	0.000	13.767	0.051
10,000	0.009	0.000	13.796	0.016

The results of the simulated methods of moments suggest that $\hat{\mu} = 0.009$ and $\hat{\rho} = 13.796$. The latter point to a fairly high correlation between income and relative preferences for manufacturing goods and services.

Next, I fix $\mu = \hat{\mu}$ and $\rho = \hat{\rho}$ and draw α_{id} conditional on the observations of country-decile nominal income levels 1000 times. I set final $\hat{\alpha}_{id}$ for each $\{i, d\}$ pair equal to the average across these draws. The range of the estimated α_{id} is [0.072, 0.933] which comfortably falls inside the unit interval. Average $\hat{\alpha}_{id}$ across all countries and all deciles is 0.9076 with standard deviation of 0.0628. Lower deciles exhibit higher variation in terms of $\hat{\alpha}_{id}$. In Table

2, I report descriptive statistics for $\hat{\alpha}_{id}$ across different deciles. The marginal propensity to

Table 2: DESCRIPTIVE STATISTICS OF $\hat{\alpha}_{id}$

decile	mean	std. deviation	min	max	decile	mean	std. deviation	min	max
d=1	0.841	0.162	0.072	0.931	d=6	0.919	0.013	0.867	0.932
d=2	0.890	0.066	0.576	0.932	d=7	0.921	0.010	0.880	0.932
d=3	0.904	0.039	0.731	0.931	d=8	0.923	0.007	0.892	0.933
d=4	0.911	0.025	0.800	0.932	d=9	0.924	0.006	0.905	0.933
d=5	0.916	0.018	0.844	0.931	d=10	0.926	0.003	0.919	0.933

consume manufacturing goods and services relative to food is higher for rich consumers. I plot $\hat{\alpha}_{id}$ against y_{id} with 95% confidence intervals (across 1,000 random draws) in the left panel of Figure 3.[26]

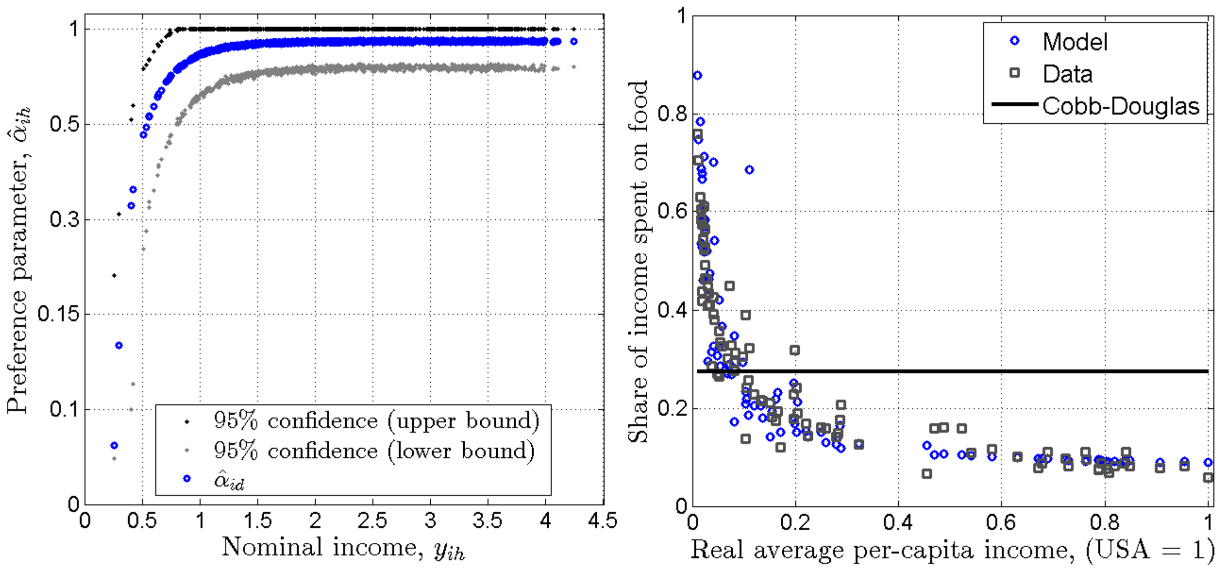

Figure 3: CALIBRATED α_{id} (LEFT PANEL) AND Υ_{ai} (RIGHT PANEL)

Finally, to check the fit of the calibrated utility function parameters to the data I use $\hat{\rho}$, $\hat{\mu}$ and $\hat{\alpha}_{id}$ to generate country-level expenditure shares on food and compare them to the data. The results are presented in the right panel of Figure 3. The predictions for Υ_{ai} of the calibrated utility function exhibit close fit to the data. The correlation between the model's prediction and the data is 0.92. This contrasts with the predictions of traditional Cobb-Douglas specification. In fact, under Cobb-Douglas preferences the share of income spent on food would be constant across countries and is represented by the solid horizontal line in the right panel of Figure 3.

[26]As α_{id} is bounded by zero and unity, the upper bound for the confidence interval is calculated as $\min(1.96\sigma_\alpha, 1)$, where σ_α is standard deviation of $\hat{\alpha}_{id}$ across 1,000 draws.

Figure 3 suggests that non-homotheticity and consumer heterogeneity are necessary for predicting total consumer demand in each country. Hence, one has to consider both when evaluating welfare gains for different consumer groups within each country. In Figure 4, I plot predictions of the calibrated model of income share spent on food for different deciles and different countries. 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 often larger than the gap between average consumers in the richest and the poorest country. For example, as far as the share of income spent on food is concerned, the difference between the richest and the poorest consumers in the USA is larger than the difference between average consumers in the USA and Mexico and/or Morocco. This suggests that non-homotheticity under ARC is not sufficient to evaluate consumer-specific welfare gains correctly.

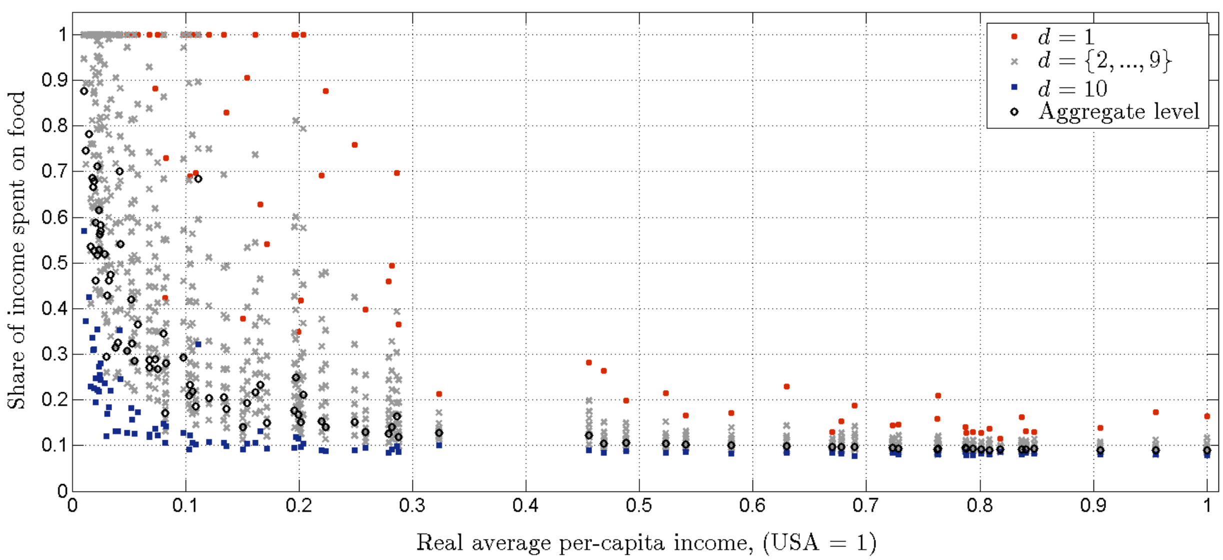

Figure 4: Expenditure Ratios versus Average Real Income per Capita

The differences in the income shares spent on agricultural goods are especially large for developing countries which is intuitive given that they are often characterised by low average level of income and relatively high dispersion thereof. Consequently, as Table 2 suggests the dispersion of preference parameter α_{id} is also higher in poor countries. The differences are less pronounced, yet still substantial, for relatively rich countries.

4.2 Parameters of production functions

The production function parameters are calculated using data on input-output tables. 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 $\{\varrho, \zeta, \epsilon, \varphi\}$ are calculated from the ratio of total non-tradable input to total manufacturing input. Cross-country averages with standard deviations of these parameters are shown in Table 3.

Table 3: Production parameters

	ϕ	ξ	γ	ϱ	ζ	ϵ	φ
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 of 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.

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

$$\frac{X_{m,ij}}{X_{m,ii}} = \left(\frac{\kappa_{mj}\tau_{m,ij}t_{m,ij}}{\kappa_{mi}}\right)^{-\theta_m} \text{ where } \tau_{m,ij} = (\tau_{m,i}\tilde{\tau}_{m,ij}\tau_{m,j}). \tag{4.4}$$

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 bilateral symmetric component $\tilde{\tau}_{m,ij}$. 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:

$$\theta_m \ln(\tilde{\tau}_{m,ij}) = \gamma_{1m}\text{adjacency}_{ij} + \gamma_{2m}\ln(\text{distance}_{ij}) \tag{4.5}$$

The two asymmetric trade cost components will be captured by the exporter fixed effect, $ex_j = -\theta_m [\ln(\kappa_{mj}) - \ln(\tau_{m,j})]$, and the importer fixed effect, $im_i = \theta_m [\ln(\kappa_{mi}) - \ln(\tau_{m,i})]$, respectively. Then, a stochastic counterpart to the structural gravity equation in (4.4) can be estimated as:

$$\frac{X_{m,ij}}{X_{m,ii}} = \exp\{ex_j + im_i - \theta_m \ln(t_{m,ij}) - \theta_m \ln(\tilde{\tau}_{m,ij})\} + error_{ij}, \tag{4.6}$$

I estimate (4.6) using Poisson Pseudo Maximum Likelihood (PPML) estimator which belongs to the class of estimators based on the linear exponential families (Gourieroux, Monfort and Trognon, 1984). Santos Silva and Tenreyro (2006) show that this estimator has several advantages over OLS and non-linear least squares in estimating structural gravity equations as in (4.6). It is consistent in the presence of heteroskedasticity and can naturally handle the problem of zeros which is pertinent to the data on international trade flows.[27]

Notice that in (4.6) the coefficient on tariffs between i and j identifies θ_m.[28] I estimate θ_a using the data on $X_{a,ij}$ and $t_{a,ij}$ in the same fashion. The estimates of $\theta_m = 6.53$ and $\theta_a = 12.07$ along with the respective standard errors are reported in Table 4.[29] The estimated values of θ_a

Table 4: Production parameters

parameter	estim.	std. error	parameter	estim.	std. error
γ_{1a}	0.164	0.224	γ_{1m}	0.615	0.183
γ_{2a}	-0.438	0.073	γ_{2m}	-0.322	0.066
$-\theta_a$	-12.072	1.160	$-\theta_m$	-6.539	1.235

Notes: Standard errors are based on Eicker-White sandwich estimates and are robust to heteroskedasticity of an unknown form. Exporter and importer fixed effects are included in the regression.

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. Costinot, Donaldson and Komunjer (2012) use productivity data of the manufacturing sector and estimate $\theta = 6.5$.

The fact that $\theta_m < \theta_a$ is of the first-order importance for the main results because under an equivalent reduction in trade costs the price of m_i would fall relatively more. Hence, consumers with higher income and higher preferences for manufacturing goods would experience larger gains from trade. This issue is discussed more formally in the next section.

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

[28] 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.

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

5 Sources of heterogeneity in the welfare gains

In Section 3.2, I used a simplistic example to show that consumers experience heterogeneous welfare gains from trade whenever p_{ni}, p_{mi} and p_{ai} change in an asymmetric manner. Hence, relative magnitudes of θ_m and θ_a are of first-order importance because under symmetric reduction in trade costs productivity dispersion parameters inversely determine the welfare gains from trade. Intuitively, with lower θ the right tail of the productivity distribution is fatter. In other words, lower θ means that there is a larger mass of firms with high productivity (low prices) in the right tail of the distribution such 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 centred 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 agricultural and manufacturing sectors in (3.16) and (3.13), respectively.

Benchmark values of θ_m and θ_a suggest that the degree of heterogeneity in productivity is much lower in the the agricultural sector. This is depicted in the left panel of Figure 5 where I plot two Frèchet distributions with identical scale parameter ($\lambda = 1$) but different θ's.

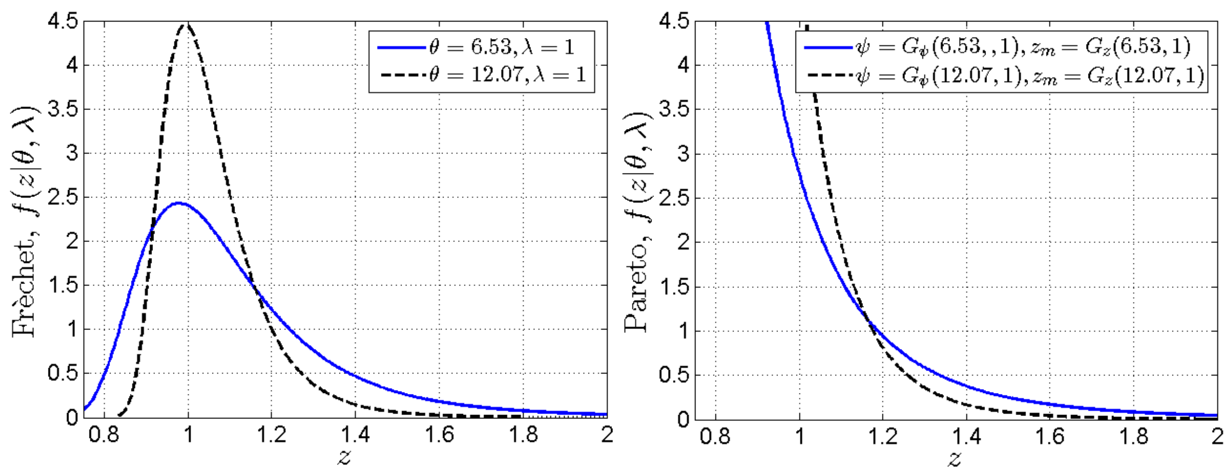

Figure 5: Examples of Frèchet (left panel) and Pareto (right panel) distributions

The intuition behind the inverse relationship prices and the dispersion parameter, θ, is not driven by specific distributional assumptions. In the right panel of Figure 5, I plot Pareto density functions that suggest identical results, i.e., the right tail of the productivity distribution is fatter whenever θ is lower. To make two distributions comparable, I assume that the first two moments of Frèchet and Pareto distributions are equal. This allows me to express parameters of the latter as functions of the former such that $\psi = G_\psi(\theta, \lambda)$ and $z_m = G_z(\theta, \lambda)$, where ψ and z_m are shape and scale parameters of the Pareto distribution, respectively. Unfortunately, under the assumption of Pareto distributions of productivity the model would lose its analytic elegance and would need to be solved numerically. However, the general results of the model would remain. To prove this, I solve a version of the model that features Pareto distributions in the Appendix.

In addition to the immediate differences in the productivity dispersion parameters, manufacturing and agricultural sectors experience different changes in prices due to different use of intermediate inputs. Firms in the manufacturing sector use manufacturing aggregate as intermediate input relatively more intensively because $(1-\zeta)(1-\xi) > \varphi(1-\gamma)$. On the other hand, firms in the agricultural sector use output of the agricultural sector more intensively. Hence, the difference between θ_m and θ_a is amplified by asymmetry in the intensity of the intermediate inputs such that p_{mi} and p_{ni} experience larger decrease relative to p_{ai}.

6 Counterfactual experiments

For the counterfactual experiments, it is useful to express the model in relative changes. I assume that the primitives of the model τ_{ij} and λ_i do not respond to indirect shocks such that $\widehat{\tau}_{ij} = 1$ and $\widehat{\lambda}_{ij} = 1$ (unless otherwise noted) and conduct counterfactual experiments without having to estimate these unobservable fundamentals.[30]The counterfactual outcomes are calculated in the spirit of Dekle, Eaton and Kortum (2007). Details on how to apply this approach in models with non-homothetic preferences and heterogeneous consumers 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 experiments are close to each other in terms of 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.

6.1 Two measures of the welfare gains under ARC

Perhaps, the most commonly used metric for the welfare gains from trade is measuring change in real income under ARC with homothetic (e.g. Cobb-Douglas) preferences. This benchmark has been overwhelmingly dominant in both theoretical and empirical research

[30]The initial levels of λ_{ij} and τ_{ij} are implicitly included in the data on trade flows. Hence, all counterfactual experiments are conducted conditional on these levels.

that analyses welfare implications of international trade and also appears to be the most widely used by policy makers. Hence, it is natural to use this measure as the first benchmark. In terms of the model considered here, a *representative consumer with homothetic Cobb-Douglas preferences* (hereafter CB) has utility function of the form:

$$U_{i,CB}(n_i, m_i, a_i) = \left(n_i^{\beta_{CB}} m_i^{1-\beta_{CB}}\right)^{\alpha_{CB}} a_i^{1-\alpha_{CB}}, \tag{6.1}$$

where β_{CB} and α_{CB} lie inside the unit interval. Let $\Delta_{i,CB} = 100 \times ev_{i,CB}$ where $ev_{i,CB}$ is defined as equivalent variation normalized by the initial income as in (3.9). In other words, $\Delta_{i,CB}$ measures welfare gains from trade in percent for CB. Naturally, calculating $\Delta_{i,CB}$ requires solving the model and calibrating its parameters to CB preferences. I provide details in the Appendix.

The second metric for the gains from trade that I consider is the welfare change of a *single representative consumer with non-homothetic preferences* (hereafter NHS). This benchmark can potentially account for different consumption patterns between countries but not for consumption differences due to consumer heterogeneity within each country. The corresponding utility function of NHS is as follows:

$$U_{i,NHS}(n_i, m_i, a_i) = \left(n_i^{\beta_{NHS}} m_i^{1-\beta_{NHS}} + \frac{\mu_{NHS}\alpha_{NHS}}{1-\alpha_{NHS}}\right)^{\alpha_{NHS}} a_i^{1-\alpha_{NHS}}, \tag{6.2}$$

, where β_{NHS}, α_{NHS}, μ_{NHS} satisfy usual restrictions and are common to all countries and consumers. The welfare gains (in percent) for NHS are measured as $\Delta_{i,NHS} = 100 \times ev_{i,NHS}$. I provide calibration algorithm and parameter values in the Appendix.

I now turn to quantifying the differences between welfare gains from trade predicted by the model with non-homothetic preferences and heterogeneous consumers Δ_{id} and the two benchmarks $\Delta_{i,CB}$ and $\Delta_{i,NHS}$. In particular, I use $\Delta_{i,CB} - \Delta_{id}$ and $\Delta_{i,NHS} - \Delta_{id}$ to measure by how many percentage points CB and NHS overestimate the welfare gains from trade for each consumer decile.

6.2 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:

$$\widehat{\tau}_{ij} = \begin{cases} 0.85 \text{ if } i \neq j \\ 1 \quad \text{if } i = j. \end{cases} \tag{6.3}$$

This experiment is *clean* in the 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. I calculate $\Delta_{i,CB}$ and $\Delta_{i,NHS}$, and plot them in two upper panels of Figure 6. The results indicate that

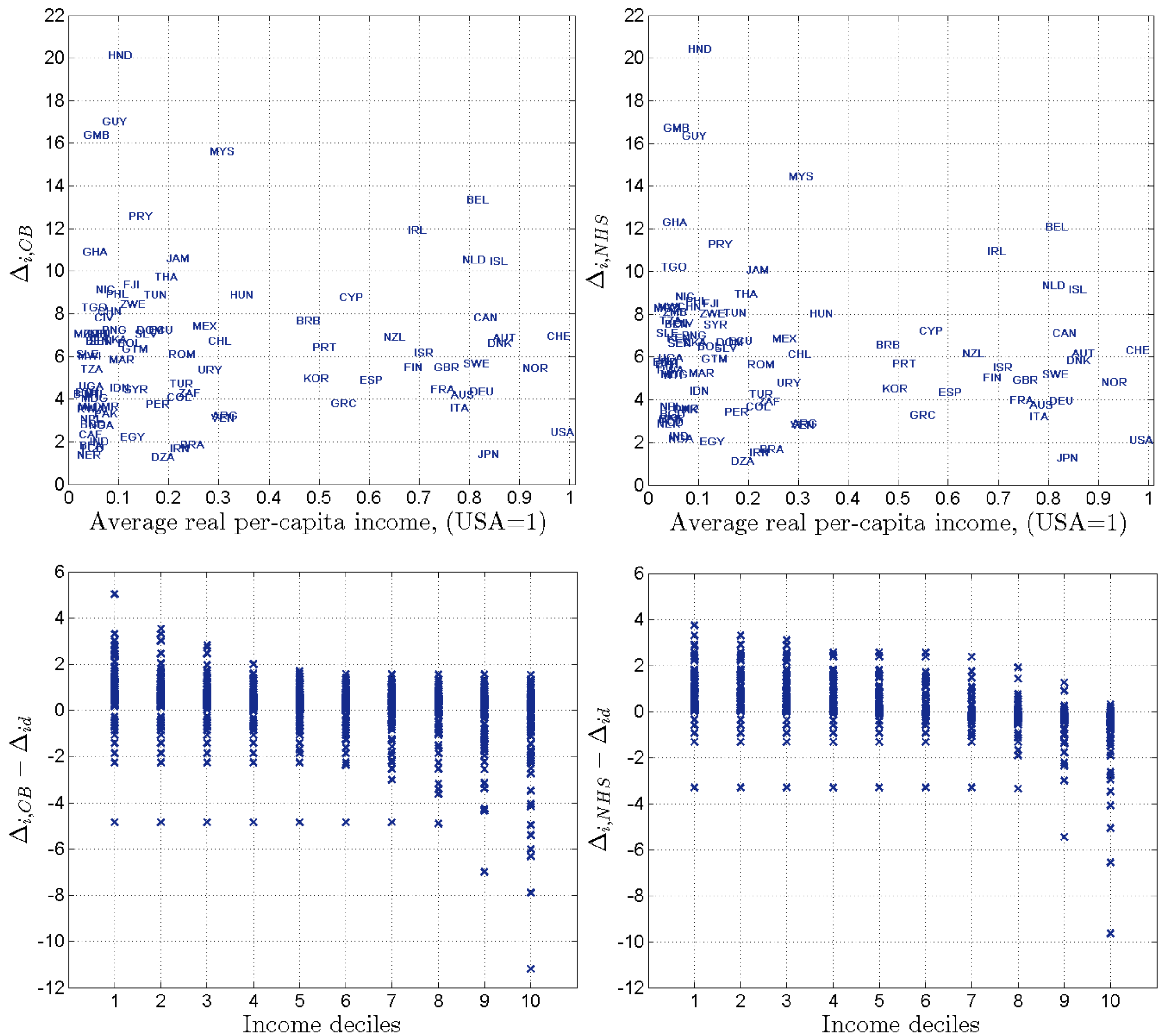

Figure 6: Results of Experiment 1

average consumers in all countries would gain from a costless trade liberalisation. Smaller countries tend to gain relatively more which is consistent with the literature (see Alvarez and Lucas, 2007). Next, I calculate the measurement error induced by ARC for CB and NHS, $\Delta_{i,CB} - \Delta_{id}$ and $\Delta_{i,NHS} - \Delta_{id}$, and plot them against consumer deciles in the lower two panels of Figure 6. Both CB and NHS tend to overpredict welfare gains for consumers

Table 5: Counterfactual change in variables in % (Experiment 1)

	w_i	p_{ai}	p_{ni}	p_{mi}	Δ_{i1}	Δ_{i2}	Δ_{i3}	Δ_{i4}	Δ_{i5}	Δ_{i6}	Δ_{i7}	Δ_{i8}	Δ_{i9}	Δ_{i10}	$\Delta_{i,CB}$	$\Delta_{i,NHS}$
ARG	3.48	1.82	2.55	-0.88	2.54	2.71	2.77	2.81	2.84	2.86	2.88	2.89	2.90	2.93	3.22	2.88
AUS	2.69	0.71	1.51	-2.82	3.53	3.69	3.71	3.72	3.73	3.74	3.75	3.75	3.77	3.77	4.19	3.75
AUT	3.13	-0.76	1.25	-5.59	6.05	6.10	6.11	6.12	6.13	6.14	6.14	6.15	6.16	6.17	6.85	6.17
BDI	12.60	3.23	6.13	-15.26	9.07	9.07	9.07	9.07	9.07	9.07	9.07	9.12	11.22	15.42	4.22	5.76
BEL	9.59	-0.55	5.90	-7.04	11.94	11.97	11.99	11.99	12.00	12.00	12.00	12.01	12.02	12.02	13.36	12.06
BEN	2.27	-3.30	-0.72	-11.30	5.76	5.98	6.69	7.18	7.61	7.96	8.28	8.57	8.93	9.46	6.71	7.54
BFA	-4.11	-5.62	-4.97	-8.20	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.65	2.17	2.77	1.82	3.07
BGD	2.14	-0.24	0.61	-5.03	2.39	2.39	2.41	2.77	3.05	3.30	3.52	3.77	4.03	4.51	2.80	3.31
BOL	2.83	-1.86	0.68	-7.09	4.78	4.78	4.98	5.57	5.95	6.21	6.42	6.61	6.79	7.03	6.59	6.49
BRA	0.86	-0.29	0.34	-1.60	1.23	1.46	1.53	1.58	1.61	1.63	1.64	1.66	1.67	1.69	1.84	1.65
BRB	0.40	-5.44	-1.49	-8.37	6.48	6.52	6.53	6.53	6.54	6.54	6.55	6.55	6.56	6.56	7.69	6.55
CAF	-1.53	-3.50	-2.55	-6.32	2.05	2.05	2.05	2.05	2.05	2.05	2.21	2.59	2.90	3.26	2.32	3.10
CAN	5.24	0.53	3.06	-4.84	6.93	7.00	7.02	7.04	7.05	7.05	7.07	7.08	7.07	7.08	7.82	7.09
CHE	3.94	0.18	2.00	-5.05	6.05	6.21	6.24	6.26	6.27	6.28	6.29	6.29	6.29	6.31	6.94	6.31
CHL	5.34	1.33	3.40	-3.64	5.33	5.72	5.85	5.93	5.99	6.03	6.08	6.11	6.17	6.23	6.73	6.12
CHN	7.80	2.15	4.69	-6.36	5.54	6.53	7.22	7.68	8.05	8.37	8.63	8.90	9.15	9.55	8.11	8.36
CIV	9.73	2.36	7.19	-1.92	7.26	7.49	7.62	7.71	7.77	7.82	7.86	7.90	7.94	8.02	7.81	7.57
CMR	3.66	0.93	2.45	-2.04	2.70	2.70	2.78	3.06	3.26	3.41	3.53	3.63	3.73	3.86	3.64	3.55
COL	1.07	-1.61	-0.08	-4.33	2.73	3.25	3.42	3.52	3.59	3.64	3.68	3.71	3.75	3.81	4.07	3.68
CYP	-1.09	-5.98	-3.17	-10.70	7.05	7.12	7.14	7.16	7.18	7.18	7.19	7.20	7.21	7.22	8.75	7.23
DEU	2.11	-0.70	0.92	-3.47	3.86	3.88	3.88	3.89	3.89	3.89	3.90	3.90	3.90	3.90	4.34	3.91
DNK	4.81	0.12	3.03	-3.45	5.71	5.76	5.77	5.78	5.79	5.79	5.80	5.81	5.81	5.81	6.61	5.83
DOM	3.80	-1.66	1.73	-5.77	5.86	6.32	6.48	6.57	6.63	6.68	6.72	6.76	6.80	6.86	7.21	6.67
DZA	-10.35	-11.23	-10.68	-11.89	1.07	1.11	1.13	1.14	1.15	1.16	1.16	1.17	1.18	1.18	1.25	1.13
ECU	7.00	1.99	4.77	-3.31	4.91	5.64	6.08	6.32	6.50	6.62	6.74	6.84	6.94	7.08	7.23	6.73
EGY	-7.23	-8.85	-7.83	-10.07	1.91	1.99	2.03	2.05	2.07	2.08	2.10	2.11	2.12	2.15	2.23	2.04
ESP	1.91	-1.31	0.60	-4.21	4.22	4.27	4.28	4.28	4.29	4.30	4.30	4.31	4.31	4.32	4.87	4.32
ETH	7.24	0.62	2.66	-13.04	6.57	6.57	6.57	6.57	6.57	6.57	6.57	6.57	7.43	12.20	4.31	5.63
FIN	3.60	0.42	2.05	-3.66	4.95	4.98	4.99	5.00	5.01	5.01	5.02	5.02	5.02	5.05	5.46	5.04
FJI	8.69	0.98	5.98	-3.71	8.05	8.36	8.46	8.52	8.55	8.58	8.61	8.64	8.66	8.70	9.34	8.51
FRA	2.18	-0.63	0.98	-3.47	3.89	3.91	3.92	3.94	3.94	3.94	3.94	3.95	3.95	3.96	4.45	3.97
GBR	2.18	-1.10	0.69	-4.77	4.80	4.83	4.85	4.86	4.87	4.88	4.88	4.88	4.90	4.90	5.46	4.90
GHA	10.70	1.18	5.75	-11.17	9.41	9.41	9.46	10.58	11.45	12.20	12.84	13.45	14.10	15.08	10.91	12.31
GMB	11.55	-3.98	6.40	-11.13	16.17	16.17	16.17	16.25	16.47	16.64	16.76	16.88	16.98	17.10	16.39	16.72
GRC	-1.89	-4.38	-2.84	-6.37	3.17	3.22	3.23	3.24	3.25	3.25	3.25	3.25	3.26	3.26	3.79	3.27
GTM	4.22	-0.64	2.35	-4.47	4.89	5.24	5.53	5.68	5.79	5.87	5.93	5.99	6.05	6.13	6.35	5.89
GUY	14.37	-2.02	9.20	-8.41	16.72	16.74	16.75	16.76	16.77	16.77	16.77	16.78	16.78	16.79	16.99	16.37
HND	14.53	-2.21	7.77	-14.52	17.12	17.12	17.31	18.59	19.42	20.07	20.55	20.99	21.38	21.93	20.13	20.41
HTI	-2.49	-7.23	-3.90	-9.05	5.11	5.11	5.11	5.11	5.11	5.10	5.08	5.06	5.03	5.01	4.24	5.14
HUN	4.92	0.06	2.41	-6.61	7.75	7.89	7.95	7.97	8.00	8.01	8.03	8.05	8.08	8.12	8.89	8.02
IDN	2.72	-0.33	1.21	-4.33	3.66	4.01	4.17	4.27	4.37	4.45	4.52	4.59	4.68	4.82	4.52	4.42
IND	3.21	1.70	2.12	-1.90	1.49	1.49	1.51	1.78	2.00	2.20	2.39	2.58	2.79	3.11	1.99	2.28
IRL	9.82	1.02	6.42	-5.59	10.79	10.84	10.87	10.88	10.89	10.90	10.90	10.92	10.93	10.94	11.90	10.93
IRN	-3.97	-5.04	-4.43	-6.19	1.14	1.25	1.36	1.42	1.46	1.49	1.52	1.54	1.57	1.60	1.66	1.52
ISL	9.49	2.43	6.62	-3.62	9.00	9.06	9.08	9.08	9.08	9.10	9.10	9.12	9.11	9.12	10.44	9.14
ZWE	2.02	-1.44	0.35	-5.74	5.30	5.38	5.41	5.43	5.46	5.47	5.48	5.48	5.50	5.51	6.16	5.50
ISR	1.79	-0.74	0.83	-2.75	3.13	3.16	3.17	3.17	3.17	3.18	3.18	3.18	3.18	3.19	3.57	3.20
ITA	5.39	-3.05	2.23	-8.98	8.71	9.23	9.64	9.86	10.02	10.14	10.25	10.33	10.42	10.54	10.61	10.06
JAM	-0.30	-1.42	-0.67	-2.08	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.42	1.26
JPN	6.58	1.91	4.14	-4.66	4.58	4.58	5.08	5.71	6.14	6.49	6.78	7.04	7.27	7.66	7.04	6.87
KEN	1.92	-0.84	0.54	-4.53	4.20	4.40	4.44	4.46	4.47	4.48	4.48	4.49	4.50	4.52	4.96	4.50
KOR	4.61	-1.28	2.46	-5.35	6.19	6.50	6.62	6.70	6.77	6.82	6.87	6.92	6.98	7.07	6.80	6.66
LKA	2.37	-2.11	0.77	-5.11	5.09	5.17	5.21	5.24	5.26	5.28	5.30	5.31	5.33	5.35	5.82	5.24
MAR	4.28	0.60	2.15	-5.56	3.66	3.66	3.66	3.66	3.66	3.90	4.50	5.04	5.55	6.33	4.04	5.17
MDG	4.77	0.21	2.60	-5.27	5.31	6.19	6.46	6.61	6.70	6.78	6.85	6.91	6.97	7.05	7.40	6.86
MEX	-0.09	-3.41	-1.86	-8.33	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.88	4.55	5.60	3.64	5.80
MLI	5.45	-3.16	0.97	-14.44	8.89	8.89	8.89	8.89	8.89	8.89	9.22	10.21	11.30	13.36	7.04	8.29
MOZ	7.80	1.16	4.01	-9.26	6.57	6.57	6.57	6.57	6.57	6.57	7.00	7.80	8.56	9.40	10.98	6.02	8.35
MWI	11.51	1.52	6.91	-8.92	12.79	13.59	13.89	14.09	14.24	14.32	14.44	14.52	14.58	14.71	15.63	14.44
MYS	-5.75	-7.41	-6.83	-10.83	1.79	1.79	1.79	1.79	1.79	1.79	1.83	2.23	2.63	3.22	1.39	2.88
NER	-0.61	-3.97	-2.77	-10.58	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49	4.39	6.26	2.78	2.16
NGA	6.87	-0.84	4.02	-6.14	7.77	7.77	8.19	8.48	8.67	8.82	8.94	9.04	9.14	9.29	9.12	8.82
NIC	7.02	-1.00	4.20	-5.87	9.21	9.24	9.25	9.26	9.27	9.27	9.27	9.27	9.28	9.29	10.52	9.32
NLD	1.88	-0.88	0.42	-4.96	4.68	4.74	4.75	4.76	4.77	4.78	4.78	4.79	4.81	4.80	5.45	4.80
NOR	3.02	0.63	1.39	-4.57	2.37	2.37	2.37	2.37	2.62	3.04	3.42	3.79	4.16	4.83	3.05	3.66
NPL	6.60	2.50	4.66	-2.40	5.84	6.03	6.07	6.09	6.10	6.12	6.14	6.14	6.15	6.17	6.90	6.14
NZL	1.69	-0.87	0.35	-4.57	2.58	2.99	3.19	3.34	3.46	3.56	3.67	3.77	3.90	4.19	3.30	3.51
PAK	1.82	-1.20	0.76	-3.18	3.12	3.31	3.37	3.41	3.44	3.46	3.47	3.49	3.50	3.53	3.74	3.42
PER	5.17	-0.82	2.27	-8.04	6.23	7.28	7.77	8.10	8.37	8.58	8.77	8.95	9.12	9.37	8.90	8.62
PHL	6.98	1.14	4.65	-3.75	5.78	6.17	6.48	6.70	6.86	6.99	7.10	7.20	7.30	7.44	7.23	7.00
PNG	1.29	-3.18	-0.40	-6.55	5.56	5.61	5.64	5.64	5.66	5.67	5.67	5.68	5.68	5.69	6.41	5.69
PRT	5.21	-2.18	1.61	-11.01	7.55	9.05	10.11	10.58	10.90	11.16	11.36	11.54	11.69	11.91	12.58	11.28
PRY	2.12	-1.65	0.34	-6.14	5.32	5.51	5.58	5.63	5.66	5.68	5.71	5.73	5.77	5.82	6.11	5.65
ROM	2.15	-2.33	0.21	-6.84	4.59	4.59	4.59	4.59	4.59	4.59	4.83	5.16	5.49	6.04	3.52	5.38
RWA	3.41	-2.65	1.31	-6.29	6.23	6.23	6.24	6.43	6.56	6.67	6.75	6.83	6.90	7.01	6.72	6.64
SEN	5.06	-1.23	2.46	-6.87	6.37	6.37	6.37	6.41	6.77	7.07	7.33	7.59	7.86	8.26	6.09	7.12
SLE	3.01	-2.34	1.02	-6.20	5.48	5.92	6.18	6.30	6.38	6.44	6.49	6.53	6.58	6.63	7.05	6.43
SLV	3.63	0.32	2.03	-3.83	5.10	5.14	5.14	5.14	5.16	5.16	5.16	5.17	5.17	5.18	5.64	5.18
SWE	0.33	-5.24	-3.11	-15.14	5.87	5.87	5.87	5.87	5.87	6.09	6.99	7.87	8.81	10.47	4.46	7.51
SYR	-0.79	-2.96	-2.04	-6.68	2.24	2.24	2.24	2.24	2.24	2.24	2.39	2.73	3.08	3.64	1.69	2.93
TCD	7.17	-0.76	2.63	-12.98	8.00	8.00	8.07	9.13	9.98	10.67	11.30	11.91	12.59	13.70	8.29	10.22
TGO	7.30	2.08	4.39	-5.96	7.34	8.06	8.39	8.57	8.72	8.83	8.95	9.02	9.12	9.23	9.73	8.94
THA	3.89	-1.72	1.40	-7.51	7.48	7.77	7.88	7.95	8.00	8.05	8.09	8.11	8.16	8.21	8.87	8.05
TUN	0.31	-2.08	-1.02	-5.92	3.72	3.98	4.08	4.14	4.20	4.23	4.27	4.30	4.33	4.39	4.70	4.26
TUR	6.84	1.63	3.59	-7.92	5.13	5.13	5.13	5.13	5.13	5.13	5.96	6.94	7.95	9.46	5.40	7.69
TZA	7.77	3.49	5.24	-3.87	4.14	4.14	4.14	4.14	4.14	4.25	4.94	5.60	6.28	7.32	4.59	5.95
UGA	4.21	0.71	2.71	-2.79	4.40	4.60	4.67	4.71	4.74	4.77	4.78	4.80	4.82	4.84	5.36	4.78
URY	0.00	-1.11	-0.66	-3.13	2.07	2.12	2.13	2.14	2.15	2.15	2.15	2.15	2.16	2.16	2.38	2.16
USA	-2.93	-4.82	-3.77	-6.93	2.31	2.60	2.69	2.74	2.77	2.80	2.82	2.84	2.86	2.89	3.10	2.80
VEN	0.34	-1.90	-0.87	-5.37	2.90	3.30	3.48	3.60	3.69	3.76	3.83	3.88	3.94	4.01	4.28	3.88
ZAF	5.21	-0.43	2.32	-7.98	5.66	5.66	5.66	5.66	5.70	6.55	7.22	7.80	8.34	9.12	7.05	8.09
ZMB	4.99	-0.12	2.36	-7.05	5.12	5.12	5.71	6.46	6.99	7.40	7.70	7.96	8.20	8.53	8.43	8.02

in lower deciles and underpredict them for higher deciles. The magnitude of the errors is large. The lower left panel suggests that for CB the measurement errors from ARC are between 5 and -11 percentage points. Since NHS preferences account for consumption differences between countries, the measurement errors are smaller for NHS than for CB. They, however, are also of substantial magnitude and lie between 4 and -10 percentage points for the poorest and the richest decile, respectively. Such range is substantial given that the average predictions of the welfare gains are between 1 and 21%.

I provide counterfactual results for each decile as well as report changes in wages and prices in Table 5. 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 as confirmed in Table 5. 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.

6.3 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 across different countries. Poor countries imposed relatively higher tariffs especially in the agricultural sector. Hence, the counterfactual elimination of all tariffs involves changes in the following manner:

$$t'_{a,ij} = 1 \text{ and } t'_{m,ij} = 1 \text{ such that } \widehat{t}_{a,ij} = (t_{a,ij})^{-1} \text{ and } \widehat{t}_{m,ij} = (t_{m,ij})^{-1} \text{ for all } i, j. \quad (6.4)$$

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

Trade liberalisation is a costly process. In Experiment 1, I assumed that all trade costs were 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 liberalisation 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, the data indicate that the share of tariff revenues in total GDP is not innocuous. The data suggest that for some poor countries, such as Tunisia, tariff revenues constitute more than

7% of the total GDP. Naturally, for most rich countries, the share of tariff revenues in total expenditure is fairly small. In 1996, on average tariff revenues constituted 2.39% of GDP with standard deviation of 1.79%. The model's prediction are in line with the data, and the predicted average share of tariff revenues in GDP is 2.24% with standard deviation of 1.62%.[31]

I assume that tariff revenues, R_i, are 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. Once I have R_i, I can calculate post-liberalisation level of income for each consumer as $\ell_{id}(w_i' - R_i/L_i)$. This also has implications for wages and prices that are endogenous to consumer income as the market clearing condition becomes:

$$(L_i w_i' - R_i) \sum_{j=1}^{J} \left(S'_{mi} x'_{m,ij} + S'_{ai} x'_{a,ij} \right) + D_{mi} + D_{ai} = \sum_{j=1}^{J} (L_j w_j' - R_j) \left(S'_{mj} x'_{m,ji} + S'_{aj} x'_{a,ji} \right). \quad (6.5)$$

I calculate the welfare gains for CB and NHS in each country and plot them in the upper left and the upper right panels of Figure 7, respectively. 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. This loss is due to changes in total tariff revenues. The are two reasons for the disparities between the results in Experiments 1 and 2. First, the asymmetry in the import tariff matrix is such that relatively rich countries cannot benefit much from tariff liberalisation as they generally impose lower tariffs and especially in the manufacturing sector. Lowering import tariffs in the agricultural sector, on the other hand, would not offer significant welfare gains for the rich under ARC because they spend relatively more on manufacturing goods. This is confirmed in Figure 7 where changes in welfare of average consumers in rich countries are moderate and vary between 0 and 2%. 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 higher total reduction in import trade barriers and because consumers in those countries spend relatively larger share of income on food. This is depicted in Figure 7 where average consumers in poor countries gain relatively more as a result of global elimination of tariffs.

[31] The data on exact tariff revenues is available only for 34 countries. I calculate mean and standard deviation based on this subsample. 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 $R_i = \sum_{j=1}^{J} \left(t_{m,ij}^{-1}(t_{m,ij} - 1) X_{m,ij} + t_{a,ij}^{-1}(t_{a,ij} - 1) X_{a,ij} \right)$, where $X_{m,ij}$ and $X_{a,ij}$ are data on trade flows in the manufacturing and agricultural sectors, respectively.

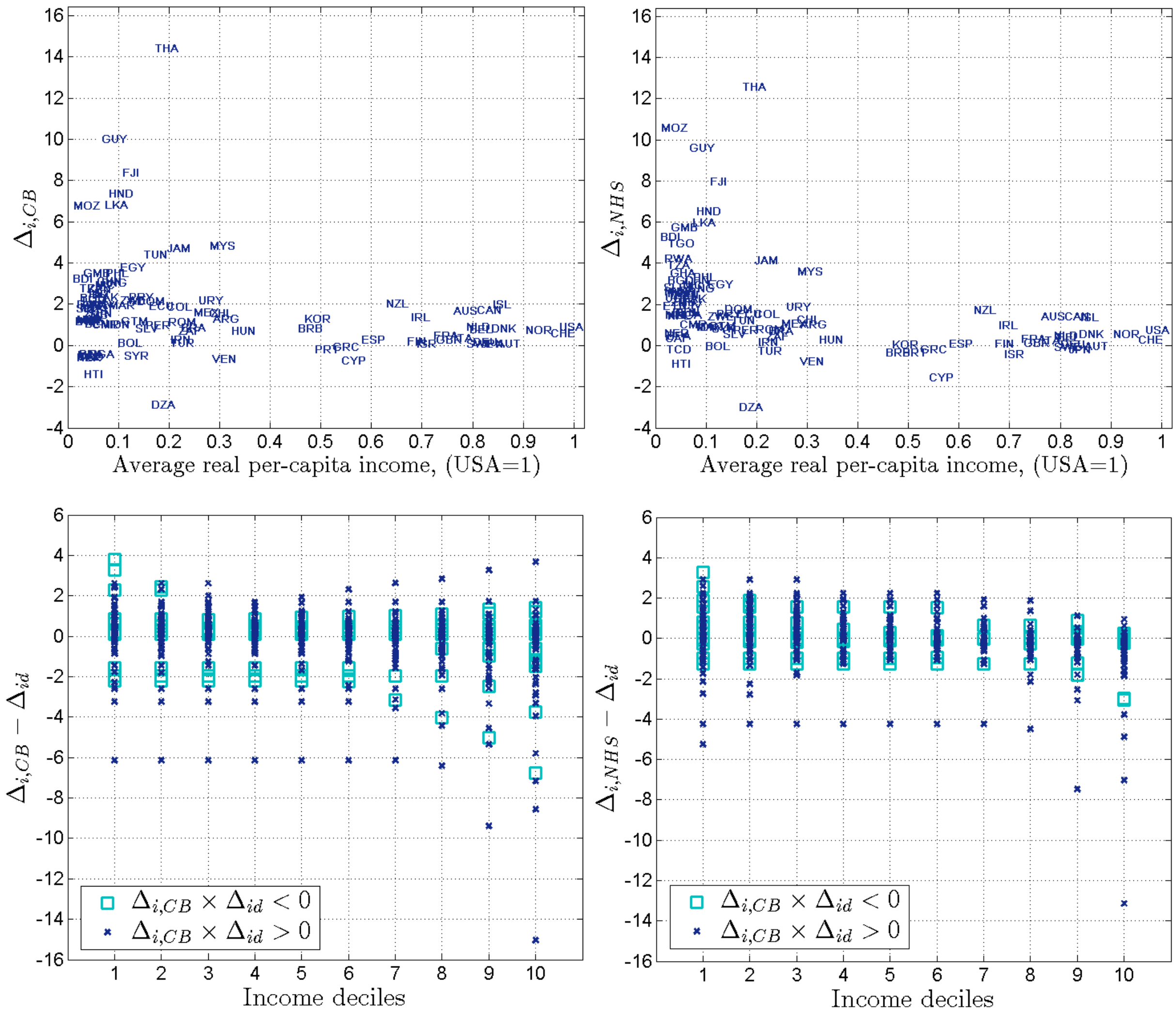

Figure 7: Results of Experiment 2

In the lower two panels of Figure 7, I plot the difference between the predictions of the change in welfare under ARC for CB and NHS, and the predictions of the model with heterogeneous consumers. Main results of this experiment are consistent with the results from Experiment 1, i.e., the measurement errors under ARC are substantial relative to the overall size of predicted welfare gains. In particular, the measurement errors for CB preferences vary between 4 (-6) and 4 (-15) percentage points for the poor and the rich, respectively. The magnitude of the measurement errors for NHS is of similar magnitude and vary between 3 (-5) and 1 (-13) percentage points for the lowest and the highest deciles.

One important difference between the results of Experiments 1 and 2 is in the qualitative differences between $\Delta_{i,CB}$ and $\Delta_{i,NHS}$, and Δ_{id}. Because Experiment 2 involves loss of tariff revenues, predictions for heterogeneous consumers may be qualitatively different from

Table 6: Counterfactual change in variables in % (Experiment 2)

	w_i	p_{ai}	p_{ni}	p_{mi}	Δ_{i1}	Δ_{i2}	Δ_{i3}	Δ_{i4}	Δ_{i5}	Δ_{i6}	Δ_{i7}	Δ_{i8}	Δ_{i9}	Δ_{i10}	$\Delta_{i,CB}$	$\Delta_{i,NHS}$
ARG	3.20	2.27	2.59	0.31	0.77	0.91	0.95	0.99	1.01	1.03	1.03	1.05	1.05	1.07	1.27	1.03
AUS	5.86	4.94	5.20	2.76	1.27	1.37	1.37	1.39	1.39	1.39	1.41	1.41	1.41	1.41	1.65	1.41
AUT	-0.05	-0.87	-0.12	-0.42	-0.03	-0.03	-0.03	-0.03	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	0.08	-0.03
BDI	7.15	-4.55	-1.02	-26.81	9.37	9.37	9.37	9.37	9.37	9.37	9.37	9.63	12.61	18.27	3.22	5.13
BEL	1.75	-0.89	1.40	0.10	0.41	0.39	0.37	0.37	0.37	0.37	0.35	0.35	0.35	0.35	0.75	0.37
BEN	1.71	-2.52	-0.66	-9.18	0.51	0.51	1.11	1.51	1.87	2.17	2.43	2.69	2.99	3.43	1.05	1.79
BFA	-8.34	-9.59	-9.29	-12.83	-0.97	-0.97	-0.97	-0.97	-0.97	-0.97	-0.97	-0.93	-0.17	0.71	-0.45	0.95
BGD	1.16	-2.41	-1.02	-8.92	1.65	1.65	1.67	2.17	2.55	2.89	3.19	3.53	3.89	4.55	2.29	2.93
BOL	-1.16	-2.50	-1.91	-4.72	-0.73	-0.73	-0.69	-0.39	-0.21	-0.07	0.03	0.11	0.21	0.33	0.11	0.07
BRA	1.98	1.29	1.54	-0.12	0.15	0.45	0.55	0.61	0.65	0.67	0.69	0.71	0.73	0.75	0.85	0.71
BRB	-3.97	-12.36	-5.09	-9.20	0.63	0.17	0.07	-0.05	-0.11	-0.15	-0.21	-0.27	-0.31	-0.39	0.81	-0.21
CAF	-7.65	-8.88	-8.32	-10.83	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.75	-0.47	-0.23	0.05	-0.54	-0.07
CAN	4.69	2.97	4.12	1.98	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.71	1.45
CHE	1.52	-0.81	1.22	0.07	0.37	0.29	0.27	0.27	0.25	0.25	0.25	0.25	0.25	0.23	0.59	0.27
CHL	3.12	1.69	2.23	-1.08	0.75	0.99	1.07	1.13	1.17	1.19	1.23	1.25	1.29	1.33	1.56	1.25
CHN	3.50	-1.64	0.62	-9.61	0.65	1.43	2.09	2.55	2.91	3.23	3.49	3.75	3.99	4.39	3.12	3.25
CIV	4.90	1.58	3.82	-0.19	1.83	1.91	1.93	1.97	1.99	1.99	2.01	2.03	2.03	2.05	1.94	1.85
CMR	-1.54	-3.79	-2.47	-5.91	0.45	0.45	0.47	0.67	0.81	0.91	0.99	1.05	1.13	1.21	1.02	0.99
COL	3.21	1.06	2.26	-1.31	0.75	1.19	1.35	1.43	1.49	1.53	1.57	1.61	1.63	1.69	1.87	1.57
CYP	-6.76	-17.76	-6.44	-5.19	-0.67	-1.11	-1.25	-1.41	-1.51	-1.55	-1.57	-1.63	-1.69	-1.79	-0.74	-1.51
DEU	0.22	-0.63	0.11	-0.30	0.05	0.05	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.16	0.05
DNK	2.90	1.09	2.64	1.69	0.59	0.53	0.53	0.53	0.53	0.51	0.51	0.51	0.51	0.51	0.81	0.53
DOM	1.34	-2.17	-0.43	-6.89	0.25	1.07	1.33	1.49	1.61	1.69	1.77	1.83	1.91	2.01	2.12	1.75
DZA	-14.16	-14.94	-14.46	-15.58	-3.03	-2.99	-2.97	-2.95	-2.95	-2.95	-2.93	-2.93	-2.93	-2.91	-2.90	-2.95
ECU	2.52	0.31	1.42	-2.64	0.55	0.93	1.21	1.37	1.47	1.55	1.63	1.69	1.75	1.85	1.88	1.63
EGY	-12.28	-16.27	-15.42	-26.38	-0.01	1.45	2.07	2.49	2.81	3.07	3.35	3.55	3.81	4.31	3.77	3.25
ESP	0.70	-0.46	0.60	0.22	0.15	0.11	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.07	0.25	0.09
ETH	1.60	-4.95	-3.05	-18.88	3.77	3.77	3.77	3.77	3.77	3.77	3.77	3.77	4.49	9.71	1.15	2.69
FIN	0.31	-0.46	0.18	-0.32	0.09	0.09	0.09	0.09	0.09	0.07	0.07	0.07	0.07	0.07	0.19	0.09
FJI	19.62	9.15	16.10	3.62	7.21	7.47	7.55	7.59	7.61	7.63	7.65	7.69	7.69	7.73	8.37	7.55
FRA	1.85	1.02	1.67	0.98	0.33	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.45	0.31
GBR	0.23	-0.83	0.05	-0.62	0.13	0.13	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.28	0.11
GHA	3.07	-3.08	0.03	-10.76	1.75	1.75	1.75	2.13	2.67	3.13	3.53	3.89	4.29	4.89	1.95	3.09
GMB	5.73	-6.15	2.18	-10.27	4.17	4.17	4.17	4.17	4.07	3.99	3.91	3.87	3.81	3.75	3.50	3.59
GRC	-1.21	-2.26	-1.23	-1.32	-0.11	-0.17	-0.19	-0.21	-0.21	-0.21	-0.21	-0.21	-0.23	-0.23	-0.07	-0.21
GTM	0.98	-0.84	0.16	-2.89	0.29	0.49	0.69	0.79	0.87	0.93	0.97	1.01	1.05	1.11	1.18	0.97
GUY	14.38	-3.40	9.69	-6.44	12.29	11.81	11.27	10.81	10.53	10.31	10.17	9.99	9.83	9.51	10.01	9.55
HND	10.13	0.75	5.79	-9.25	4.71	4.71	4.71	5.65	6.47	7.11	7.59	8.03	8.41	8.97	7.33	7.61
HTI	-6.78	-10.22	-7.28	-9.15	0.17	0.17	0.17	0.17	0.17	0.15	-0.25	-0.61	-0.97	-1.43	-1.41	-0.81
HUN	0.60	-1.91	0.25	-1.10	0.47	0.41	0.39	0.39	0.37	0.37	0.37	0.35	0.35	0.33	0.70	0.37
IDN	0.07	-1.26	-0.77	-3.92	0.29	0.57	0.69	0.77	0.83	0.89	0.95	1.01	1.07	1.17	0.99	0.91
IND	-0.20	-3.01	-2.22	-9.55	1.35	1.35	1.43	1.93	2.35	2.75	3.11	3.49	3.91	4.51	2.48	2.93
IRL	3.02	0.47	2.45	0.28	1.01	0.99	0.99	0.99	0.99	0.97	0.97	0.97	0.97	0.97	1.35	0.99
IRN	-3.51	-4.06	-3.88	-5.26	-0.35	-0.21	-0.05	0.03	0.09	0.13	0.17	0.21	0.25	0.29	0.28	0.19
ISL	5.26	1.35	4.72	2.68	1.45	1.41	1.39	1.39	1.39	1.37	1.37	1.35	1.37	1.35	1.98	1.39
ZWE	-2.98	-6.83	-3.15	-3.79	-0.11	-0.25	-0.31	-0.35	-0.39	-0.39	-0.41	-0.43	-0.45	-0.47	0.07	-0.39
ISR	1.83	1.08	1.69	1.14	0.25	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.34	0.23
ITA	5.57	-2.27	2.51	-8.35	2.75	3.25	3.71	3.97	4.13	4.27	4.41	4.49	4.59	4.73	4.68	4.25
JAM	-5.88	-8.05	-5.87	-5.84	-0.15	-0.19	-0.19	-0.21	-0.21	-0.21	-0.21	-0.23	-0.23	-0.25	0.08	-0.21
JPN	0.80	-3.52	-1.20	-8.48	1.15	1.15	1.41	1.87	2.17	2.41	2.63	2.81	2.97	3.25	2.71	2.63
KEN	-5.38	-14.60	-5.64	-6.60	1.51	0.49	0.25	0.15	0.09	0.05	0.05	0.01	-0.07	-0.15	1.27	0.09
KOR	9.01	-3.05	6.21	-3.78	8.55	7.77	7.45	7.25	7.09	6.95	6.83	6.71	6.57	6.33	6.79	6.41
LKA	-4.08	-13.96	-5.35	-10.04	2.69	2.03	1.73	1.51	1.35	1.19	1.09	0.97	0.83	0.63	1.94	0.95
MAR	9.05	6.67	7.54	2.00	1.55	1.55	1.55	1.55	1.55	1.67	2.11	2.51	2.89	3.47	1.85	2.63
MDG	0.53	-3.64	-0.85	-5.93	0.93	1.05	1.09	1.13	1.13	1.15	1.15	1.17	1.17	1.19	1.60	1.13
MEX	-2.89	-4.68	-3.95	-7.86	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63	-0.39	0.07	0.79	-0.49	0.97
MLI	13.88	0.54	8.02	-11.65	9.99	9.99	9.99	9.99	9.99	9.99	10.31	11.17	12.11	13.91	6.75	9.03
MOZ	2.11	-1.52	-0.22	-8.60	1.55	1.55	1.55	1.55	1.55	1.65	2.23	2.77	3.39	4.53	1.22	2.67
MWI	5.04	-3.73	1.69	-10.09	2.91	3.27	3.41	3.51	3.57	3.61	3.67	3.69	3.73	3.79	4.81	3.65
MYS	-5.72	-7.03	-6.63	-10.01	-0.33	-0.33	-0.33	-0.33	-0.33	-0.33	-0.33	0.03	0.37	0.89	-0.60	0.67
NER	-11.18	-16.24	-13.40	-21.34	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	2.07	3.31	-0.43	0.25
NGA	5.62	1.56	4.22	-0.94	2.45	2.45	2.57	2.67	2.75	2.79	2.83	2.87	2.91	2.97	2.90	2.75
NIC	1.72	-1.09	1.37	0.01	0.55	0.51	0.49	0.47	0.47	0.47	0.47	0.47	0.45	0.45	0.90	0.49
NLD	2.72	1.68	2.47	1.53	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.75	0.55
NOR	-4.53	-8.51	-5.46	-8.92	2.61	2.61	2.61	2.61	2.55	2.41	2.29	2.17	2.05	1.83	1.17	1.91
NPL	7.02	5.95	6.29	3.54	1.55	1.67	1.69	1.69	1.71	1.71	1.73	1.73	1.73	1.75	2.02	1.73
NZL	-2.36	-5.76	-4.25	-11.11	1.05	1.67	1.99	2.23	2.41	2.57	2.75	2.91	3.11	3.57	2.34	2.55
PAK	0.61	-1.45	-0.05	-2.52	0.69	0.75	0.77	0.77	0.79	0.79	0.79	0.81	0.81	0.81	0.98	0.75
PER	4.87	1.07	2.78	-4.84	1.09	2.01	2.45	2.75	2.97	3.15	3.33	3.49	3.63	3.85	3.50	3.25
PHL	6.60	0.70	5.23	0.20	3.89	3.63	3.39	3.23	3.09	2.99	2.91	2.83	2.75	2.65	3.04	2.69
PNG	-0.93	-2.16	-0.91	-0.87	-0.23	-0.29	-0.33	-0.33	-0.35	-0.35	-0.37	-0.37	-0.37	-0.39	-0.22	-0.35
PRT	0.87	-1.26	-0.75	-6.65	-0.97	-0.13	0.67	1.01	1.25	1.43	1.59	1.71	1.83	1.99	2.31	1.57
PRY	3.04	1.37	2.52	0.57	0.89	0.89	0.89	0.89	0.89	0.91	0.91	0.91	0.91	0.91	1.12	0.89
ROM	4.80	0.49	2.69	-4.94	2.83	2.83	2.83	2.83	2.83	2.83	3.13	3.57	4.01	4.75	1.96	3.81
RWA	0.91	-2.91	-0.74	-6.77	0.55	0.55	0.55	0.87	1.13	1.33	1.49	1.65	1.79	2.01	1.55	1.53
SEN	4.79	0.37	3.23	-2.49	2.39	2.39	2.39	2.39	2.49	2.59	2.67	2.75	2.83	2.97	1.78	2.47
SLE	-0.05	-1.81	-0.72	-3.26	0.21	0.37	0.47	0.53	0.55	0.57	0.61	0.61	0.63	0.65	0.81	0.57
SLV	0.42	-0.40	0.23	-0.48	-0.07	-0.07	-0.07	-0.07	-0.07	-0.07	-0.07	-0.07	-0.07	-0.07	0.05	-0.07
SWE	-2.84	-9.24	-6.55	-19.40	1.69	1.69	1.69	1.69	1.69	1.73	2.63	3.53	4.51	6.25	-0.51	3.27
SYR	-6.88	-7.90	-7.39	-9.32	-0.23	-0.23	-0.23	-0.23	-0.23	-0.23	-0.19	-0.07	0.05	0.25	-0.56	0.03
TCD	5.41	-1.37	1.03	-14.06	2.05	2.05	2.05	2.91	3.85	4.61	5.31	5.99	6.73	7.97	2.17	4.19
TGO	17.94	-0.14	12.41	-6.35	12.91	12.83	12.79	12.77	12.75	12.73	12.71	12.71	12.69	12.69	14.41	12.65
THA	-3.87	-24.24	-4.47	-6.74	6.91	4.45	3.49	2.91	2.49	2.09	1.77	1.57	1.15	0.73	4.41	1.67
TUN	-5.63	-8.46	-5.97	-7.24	0.29	0.05	-0.03	-0.09	-0.13	-0.17	-0.21	-0.23	-0.25	-0.31	0.11	-0.23
TUR	4.30	-1.16	1.16	-9.97	2.87	2.87	2.87	2.87	2.87	2.87	3.53	4.41	5.33	6.69	2.75	5.11
TZA	3.65	1.83	2.43	-2.07	1.03	1.03	1.03	1.03	1.03	1.03	1.41	1.77	2.15	2.73	1.26	1.97
UGA	6.31	4.69	5.44	2.16	1.51	1.69	1.75	1.79	1.81	1.83	1.85	1.87	1.87	1.89	2.16	1.85
URY	0.00	-0.72	-0.56	-2.65	0.63	0.69	0.69	0.71	0.71	0.71	0.71	0.71	0.73	0.73	0.91	0.71
USA	-6.10	-6.77	-6.40	-7.54	-0.95	-0.83	-0.81	-0.79	-0.77	-0.77	-0.75	-0.75	-0.75	-0.73	-0.66	-0.77
VEN	-1.16	-2.47	-1.86	-4.47	-0.13	0.11	0.21	0.27	0.33	0.37	0.41	0.43	0.47	0.51	0.69	0.43
ZAF	0.48	-3.07	-1.52	-8.76	0.35	0.35	0.35	0.35	0.35	0.91	1.45	1.93	2.37	2.99	1.47	2.21
ZMB	-1.04	-5.93	-3.24	-11.18	-0.13	-0.13	0.17	0.69	1.07	1.35	1.57	1.75	1.93	2.15	2.16	1.77

predictions for CB and NHS. In the lower panels of Figure 7, I use □ to denote observations where $\Delta_{i,CB} \times \Delta_{id} < 0$ and $\Delta_{i,NHS} \times \Delta_{id} < 0$. There are qualitative errors across all ten deciles. Hence, upon a costly trade liberalisation not only do CB and NHS induce significant quantitative but also qualitative errors. I report detailed results for Experiment 2 in Table 6. Notice that in some countries such as the Philippines the rich gain relatively less than the poor. This is due to the fact that in these countries the difference between the initial level of tariffs on manufacturing goods is significantly smaller than on agricultural goods. Consequently, upon complete abolishment of tariffs the price of agricultural goods fall relatively more. In this case, consistent with the model's predictions discussed in Section 3.2, the poor gain relatively more.

Overall, it is reassuring that the main results of Experiment 2 are consistent with the results of Experiment 1, i.e., the magnitude and the dispersion of the measurement errors from ARC are comparable to the dispersion of the under ARC for CB and NHS. The results in this section should be viewed as a *lower bound* of how global tariff liberalisation policy would affect consumers within and across countries as such a policy is likely to incur costs beyond loss of tariff revenues.

7 Sensitivity analysis

In this section, I analyse sensitivity of the results in the benchmark model to alternative preference and/or production structures.[32]I show that the intuition behind the main results of the benchmark model is robust to various extensions as long as the two main components of the model remain: (i) consumer demand is characterised by heterogeneous preference parameters and non-homotheticity such that relatively rich consumers value manufacturing goods relatively more and (ii) the distribution of productivities in the manufacturing sector is relatively more fat-tailed.

7.1 Monopolistic competition, variable mark-ups and selection

In this section, I show that the main results of the benchmark model are robust to extensions of monopolistic competition and variable elasticity of substitution (VES) as in Melitz and Ottaviano (2008). This framework naturally allows examining the effects of two additional

[32]I am grateful to anonymous referees for suggesting extensions in this section.

channels of the welfare gains from trade: variable mark-ups and extensive margin of trade.[33] Hence, it is important to establish robustness of the main results to extending the model in this way.[34]I provide full details of the model as well as of the numerical solution in the Appendix. Here, I focus on highlighting the main features of this extension using the example of the manufacturing sector.

In the benchmark model, lower-tier utility functions for n_i, m_i and a_i are CES. Here, I assume VES model where aggregate price indices are functions of variable mark-ups as well as measures of consumed varieties. VES model allows examining how competition effects (other than in the benchmark model) would affect qualitative results of the model. After allocating his income share for the manufacturing goods, y_m, each consumer maximises quadratic subutility function as follows (for brevity I drop consumer and country subscripts):

$$m = \left\{ \int_{\mathcal{Q}_m} m(q)dq - \frac{\upsilon_{1m}}{2} \int_{\mathcal{Q}_m} m(q)^2 dq - \frac{\upsilon_{2m}}{2} \left[\int_{\mathcal{Q}_m} m(q)dq \right]^2 \right\} \text{ s.t. } \int_{\mathcal{Q}_m} p(q)m(q) \leq y_m. \quad (7.1)$$

where q denotes different varieties in subset $\mathcal{Q}_m$. Parameters υ_{1m} and υ_{2m} measure the degree of product differentiation across varieties and the degree of substitutability of different varieties in each of the sectors, respectively.[35]Following Eckel and Neary (2010), I drop the usual assumption of the outside good, so that wages are determined endogenously. Maximizing subutility function in(7.1) leads to a well-known linear demand for each variety.

The production side is characterised by monopolistic competition and largely follows Melitz and Ottaviano (2008) without an outside sector as in Eckel and Neary (2010) and Simonovska (2010). Each country is inhabited by a measure of potential producers. Upon paying some fixed cost, each firm draws a productivity parameter, q, from a Pareto distribution with scale parameter q_{min} and shape parameter $\widetilde{\theta}$. Due to selection effects only a subset of potential firms operates in each country and even a smaller subset exports and due to the VES specification in (7.1) mark-ups are firm-specific and depend on the productivity draw and characteristics of the destination market. This is evident from the optimal pricing rule

[33]Goldberg, Khandelwal, Pavcnik and Topalova (2010) and Amiti and Konings (2007) discuss the importance of the extensive margin of trade for consumer welfare. This margin may differ from intensive margin as Bernard, Jensen, Redding and Schott (2009) find that extensive and intensive margins have different elasticities to trade costs. Here and in the Appendix, I show that the main results of the model are robust to inclusion of endogenous extensive margin.

[34]Due to computational complexity and lack of data I do not calibrate the model to the 92 countries as in the benchmark model. Instead, I solve and simulate the model for two asymmetric countries and show that the results are qualitatively identical to the benchmark model.

[35] Di Comite, Thisse and Vandenbussche (*forthcoming*) show how this preference structure can be extended to heterogeneous preferences for quality and horizontal differentiation.

of a firm with productivity parameter q where q_{ij}^* is the cutoff productivity for firms that choose to export from j to i:

$$p_{ij}(q) = \tau_{ij} w_j \left(\frac{1}{2q} + \frac{1}{2q_{ij}^*} \right). \tag{7.2}$$

With this subutility and production structure in mind, I conduct a counterfactual experiment where I reduce trade costs τ_{ij}. I consider two asymmetric countries and calculate counterfactual changes in the aggregate price index for different values of the productivity dispersion parameter $\widetilde{\theta}$. I provide remaining details of the open economy equilibrium, solution and parameterisation of the model in the Appendix.

In the benchmark model, heterogeneity in the welfare gains from trade stemmed from asymmetric changes in prices because of the differences in dispersion parameters across sectors. This channel of heterogeneity in the welfare gains remains here.

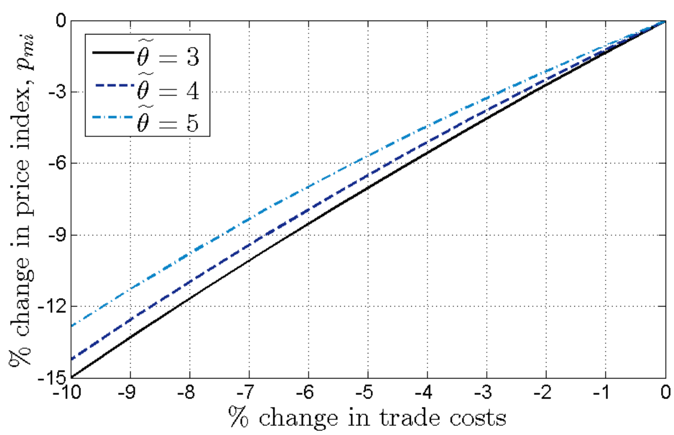

Figure 8: Trade liberalisation in VES model

In Figure 8, I plot numerical results from simulating trade liberalisation in a two-country general equilibrium model. It indicates that lower value of $\widetilde{\theta}$ (analogous to θ in the benchmark model) leads to higher reduction in the price index. Hence, extending the benchmark model to monopolistic competition with variable mark-ups and endogenous extensive margin of trade would not change the main result, i.e., as long as manufacturing and agricultural sectors are characterized by different productivity dispersion parameters, the welfare gains from trade are heterogeneous across consumers.

7.2 Monopolistic competition and quality

Recent literature has also emphasised importance of quality in the context of international trade.[36] Here, I show that the main qualitative results of the benchmark model are robust to inclusion of quality in the production structure and preferences. I largely follow Baldwin and Harrigan (2011) and consider a quality-augmented variant of Melitz (2003). As in the previous section, I use example of the manufacturing sector to establish main qualitative results. In this case, lower tier utility function is CES but with quality parameter denoted $k(q)$ specific to variety q:

$$m = \left(\int\limits_{\mathcal{Q}_m} [k(q)m(q)]^{\frac{\sigma_m - 1}{\sigma_m}} \, dq \right)^{\frac{\sigma_m}{\sigma_m - 1}} \quad \text{s.t.} \int\limits_{\mathcal{Q}_m} p(q)m(q) \leq y_m. \tag{7.3}$$

In this case, the variable of interest, namely, aggregate price index of m becomes quality-augmented as follows:

$$p_m = \left(\int\limits_{\mathcal{Q}_m} \left[\frac{p(q)}{k(q)} \right]^{1-\sigma_m} \right)^{\frac{1}{1-\sigma_m}} \tag{7.4}$$

The production structure here is identical to the one described in the previous section and features heterogeneous firms that draw productivity parameter q from a Pareto distribution. However, now the draw also defines quality, $k(q)$, of each firm as follows:

$$k(q) = q^{\varsigma}, \text{ where } \varsigma > 1. \tag{7.5}$$

Kugler and Verhoogen (2012) interpret q^{ς} as a measure of quality per physical unit of output. Then, the problem of a firm with productivity q that produces variety with quality level q^{ς} and exports from j to i can be characterized as follows:

$$p_{ij}(q) = \left(\frac{\sigma_m - 1}{\sigma_m} \right) \tau_{ij} w_j q^{\varsigma - 1} \tag{7.6}$$

Due to selection effects only a fraction of firms enter production and even fewer export. The decision of each firm to engage in production and exporting is characterised by the usual

[36] There is a growing body of work that looks at the link between 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 and find that rich consumers spend a larger share of their income on high-quality goods. Bekkers, Francois and Manchin (2012) and Fieler (2012) also argue that the average quality of consumed (imported) goods depends on the level and dispersion of income. The results in this section show how the main intuition of the benchmark model is consistent with this literature.

free entry and zero profit conditions. As in the benchmark model wages are determined endogenously. In this setting, I conduct counterfactual trade liberalisation experiments with fixed ς and σ_m but different Pareto parameter $\widetilde{\theta}$. The results are presented in Figure 9. I provide full description, solution and parameterisation of this extension in the Appendix.

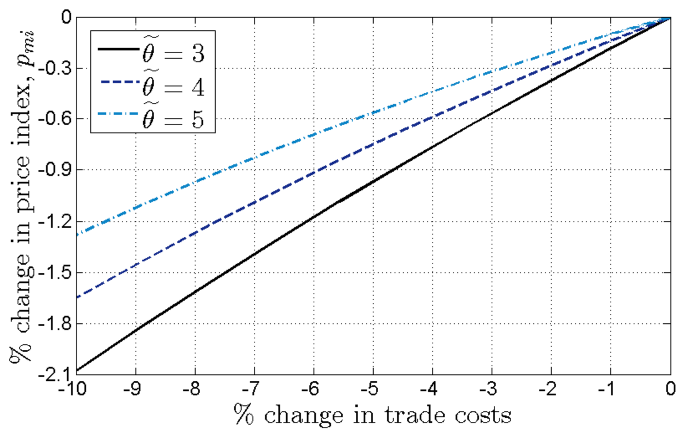

Figure 9: Trade liberalisation and quality

As before, the reduction in prices is more acute for lower values of θ. Hence, quality-augmented CES-based models produce predictions in line with the benchmark model. Intuitively, the results in Sections 7.1 and 7.2 are in the spirit of Arkolakis, Costinot and Rodriguez-Clare (2010) who point to the isomorphism of structural gravity equations of different trade models where the elasticity of trade to trade costs is captured by the analogue of θ.

7.3 Stolper-Samuelson-type effects

Trade liberalisation can often be characterized by Stolper-Samuelson-type effects when consumers experience asymmetric changes in their earnings. These effects may constitute one of the major factors that shape attitudes of the general public towards globalisation. Here, I show that the channel emphasised in the benchmark model compliments models where workers are heterogeneous in their employment statuses and/or skills. As an example, I employ the results of Burstein and Vogel (2012) who find that on average a 10% trade liberalisation leads to a 1.6% increase in the wage ratio between skilled and unskilled workers.[37]In terms of the benchmark model, it would mean that following a 10% trade liberalisation the distribution of ℓ_{id} changes, i.e., skilled consumers (defined as those who completed at least tertiary degrees) get transfer of labour endowment from everyone else.

[37]Burstein and Vogel (2012) calculate this result given full factor mobility which is one of the assumptions in the benchmark model.

I use data on the share of population with tertiary degrees from Barro and Lee (2013) to define $\ell_{e,id}$ which I associate with skilled labour. The average share of skilled labour across countries is 0.061 with standard deviation of 0.057. I assume that skilled consumers are in the highest possible decile(s), i.e., labour endowment is interpreted as endowment of human capital as in Bougheas and Riezman (2007). Then, I conduct a counterfactual experiment where I reduce all bilateral trade costs by 10% and assume that the ratio of incomes of skilled workers to unskilled workers increases by 1.6%. In the context of the model, this implies transfer of endowment from all unskilled workers (proportional to their initial income levels) to skilled workers. Hence, in this counterfactual exercise I change trade costs *and* country-specific distributions of ℓ_{id}.

Because each country experiences changes in the distribution of ℓ_{id}, consumers' incomes change asymmetrically such that even in the absence of non-homotheticity and heterogeneity in preferences there exists some variation in the welfare gains from trade. This allows comparing quantitative importance of non-homotheticity and consumer heterogeneity relative to the Stolper-Samuelson-type effects. I use $\Delta_{id,CB}$ to denote consumer-specific gains from trade due to redistribution of ℓ_{id} and define measure $\Delta_{i,CB} - \Delta_{id,CB}$ which is analogous to the notion of the measurement error under CB. I plot this measure across different deciles of consumers in the left panel of Figure 10. The figure suggests that redistribution of ℓ_{id} alone produces deviations between 2 and -2 percentage points.

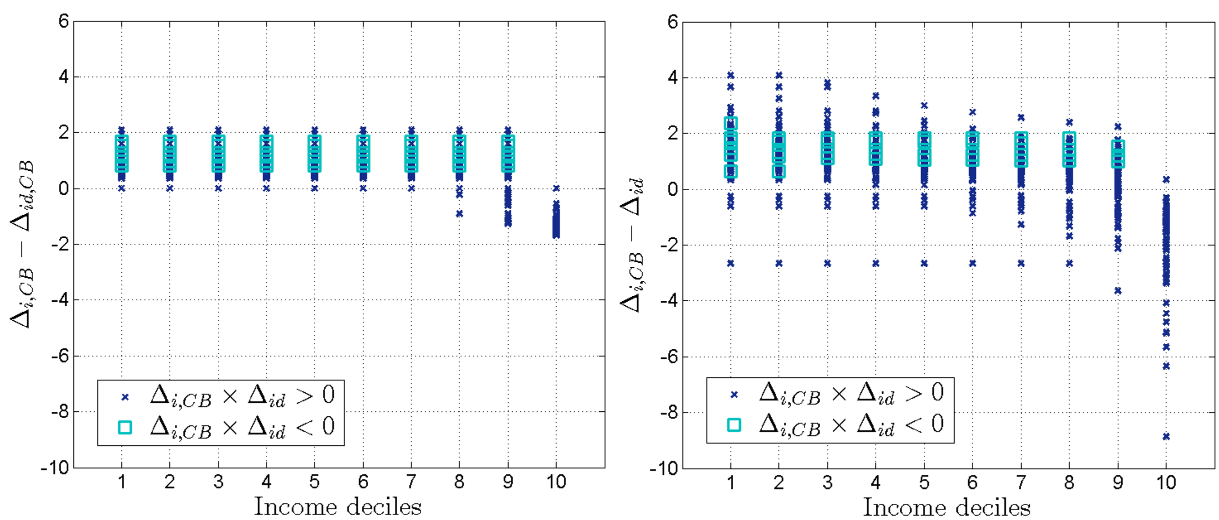

Figure 10: SKILL-PREMIUM AND TRADE LIBERALISATION

In the right panel of Figure 10, I plot the measurement error from CB calculated using the same experiment but with heterogeneous consumers and non-homothetic preferences. Here the deviations of consumer-specific welfare gains from ARC with CB are considerably larger: they lie between 4 and 9 percentage points. These results suggest that either with or without asymmetric changes in incomes, non-homotheticity and consumer heterogeneity are essential for correct evaluation of the welfare gains from trade. Figure 10 also suggests that quantitative importance of non-homotheticity and consumer heterogeneity is at least as big as importance of the Stolper-Samuelson-type effects and can act as a magnifier thereof. In fact, variation in the welfare gains from trade due to asymmetric income effects is two to five times magnified by non-homotheticity and consumer heterogeneity.

8 Conclusion

I have developed a multi-country model of trade with non-homothetic preferences, two types of consumer heterogeneity 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 liberalisation, consumers in the right tail of the income distribution have higher potential gains from trade. As it turns out, the differences in the welfare gains between different consumers can often be so large that the gains of an average consumer are no longer a relevant metric. The problem is much more acute in developing countries with low per-capita average income and high income inequality.

Under certain policy scenarios, the welfare predictions for an average consumer differ qualitatively and quantitatively from the predictions under consumer heterogeneity and non-homotheticity. 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 for the rich. These results hold potentially important policy conclusions as evaluations based on ARC may mask true welfare gains for different consumer groups and should be considered with caution.

Admittedly, one of the caveats of the model is the assumption of exogenous and stationary distribution of labour. 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.

Appendix A. Solution of the model

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 counterfactual equilibria. However, with such data[38]in hand, relative changes in prices and wages are also sufficient to determine counterfactual equilibrium trade flows and consumer welfare.

I provide details on the solution of the first experiment. The solution of the second experiment is computationally identical except for accounting for tariff revenus. 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 $\widehat{w}_i$:

$$\widehat{w}_i Y_i \sum_{j=1}^{J} \left(S'_{mi} x'_{m,ij} + S'_{ai} x'_{a,ij} \right) + D'_{mi} + D'_{ai} = \sum_{j=1}^{J} \widehat{w}_j Y_j \left(S'_{mj} x'_{m,ji} + S'_{aj} x'_{a,ji} \right), \tag{8.1}$$

where Y_i and Y_j are the data on GDP. The wage rate w_i is a measure of nominal income of an average consumer in i. Then, I can use expression in (3.3) to calculate expenditure shares of consumers in i on n_i, m_i and a_i as follows:[39]

$$\begin{aligned} \Upsilon'_{id} &= \frac{\sum_{d=1}^{10} \left\{ \underset{\widehat{w}_i y_{id} > c'_i}{\mathbf{1}} \right\} \left((1-\alpha_{id}) \widehat{w}_i y_{id} + \alpha_{id} c_i \right) + \sum_{d=1}^{10} \left\{ \underset{\widehat{w}_i y_{id} \leq c'_i}{\mathbf{1}} \right\} \widehat{w}_i y_{id}}{\sum_d \widehat{w}_i y_{id}} \\ \Upsilon'_{ni} &= \beta(1-\Upsilon'_{ai}); \quad \Upsilon'_{mi} = (1-\beta)(1-\Upsilon'_{ai}), \end{aligned} \tag{8.2}$$

Having obtained Υ'_{ai}, Υ'_{ai} and Υ'_{ai} I calculate aggregate country-level demands for n, m and a from the following equation:

$$\begin{pmatrix} S'_{ni}(L_i \widehat{w}_i) \\ S'_{mi}(L_i \widehat{w}_i) \\ S'_{ai}(L_i \widehat{w}_i) \end{pmatrix} = \begin{pmatrix} (1-\phi)\varrho & (1-\phi)(1-\varrho) & 0 \\ (1-\xi)\zeta & (1-\xi)(1-\zeta) & 0 \\ (1-\gamma)\epsilon & (1-\gamma)\varphi & (1-\gamma)(1-\epsilon-\varphi) \end{pmatrix} \begin{pmatrix} S'_{ni}(L_i \widehat{w}_i) \\ S'_{mi}(L_i \widehat{w}_i) - D_{mi} \\ S'_{ai}(L_i \widehat{w}_i) - D_{ai} \end{pmatrix} + \begin{pmatrix} \Upsilon'_{in}(L_i \widehat{w}_i) \\ \Upsilon'_{im}(L_i \widehat{w}_i) \\ \Upsilon'_{ia}(L_i \widehat{w}_i) \end{pmatrix} \tag{8.3}$$

[38]Benchmark wages of each decile were computed using data on average income and share of total wealth held by each decile.

[39]Equation in (3.3) considers continuous case. Here, I extend that formulation to account for data on deciles.

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

$$D'_{mi} = \frac{\sum_\ell \widehat{w}_\ell Y_\ell}{\sum_\ell Y_\ell} D_{mi} \;\; D'_{ai} = \frac{\sum_\ell \widehat{w}_\ell Y_\ell}{\sum_\ell Y_\ell} D_{ai} \tag{8.4}$$

The counterfactual price vector is calculated as follows:

$$p'_{mi} = p_{mi}\left(\sum_\ell^N x_{m,i\ell}(\widehat{\kappa}_{m\ell}\widehat{t}_{m,i\ell})^{-\theta_m}\right)^{-\frac{1}{\theta_t}} \quad ; \quad p'_{ai} = p_{ai}\left(\sum_\ell^N x_{a,i\ell}(\widehat{\kappa}_{a\ell}\widehat{t}_{a,i\ell})^{-\theta_a}\right)^{-\frac{1}{\theta_a}} ; \tag{8.5}$$

$$p'_{ni} = p_{ni}\widehat{w}^\phi(\widehat{p}_{ni}^{\varrho}\widehat{p}_{mi}^{1-\varrho})^{1-\phi}. \tag{8.6}$$

The counterfactual trade flows are calculated as follows:

$$x'_{m,ij} = \frac{x_{m,in}(\widehat{\kappa}_{mj}\widehat{\tau}_{m,ij})^{-\theta_m}}{\sum_\ell^N x_{m,i\ell}(\widehat{\kappa}_{m\ell}\widehat{t}_{m,i\ell})^{-\theta_m}}; \;\; x'_{a,ij} = \frac{x_{a,ij}(\widehat{\kappa}_{aj}\widehat{\tau}_{a,ij})^{-\theta_a}}{\sum_\ell^N x_{a,i\ell}(\widehat{\kappa}_{a\ell}\widehat{t}_{a,i\ell})^{-\theta_a}}, \tag{8.7}$$

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

$$\widehat{\kappa}_{mi} = \widehat{w}_i^\xi\left(\widehat{p}_{ni}^\zeta\widehat{p}_{mi}^{1-\zeta}\right)^{1-\xi}; \;\; \widehat{\kappa}_{ai} = \widehat{w}_i^\gamma\left(\widehat{p}_{ni}^\epsilon\widehat{p}_{mi}^\rho\widehat{p}_{ai}^{1-\epsilon-\rho}\right)^{1-\gamma}; \tag{8.8}$$

These two equation close the system. Overall, equations in (8.1)-(8.8) formulate a $\{92\times15+92\times92\times2\}$ system of equations that can be solved for $\{92\times15+92\times92\times2\}$ unknowns. The numeraire is $w_{USA} = w'_{USA} = 1$.

Solution of CB and NHS

The difference between the benchmark model and models with CB and NHS lies in calculation of expenditure share Υ_{ai}, Υ_{ni} and Υ_{mi}. In CB case, Υ_{ai} is invariant to changes in income and stays constant. I calculate it as the average share of income spent on food across all countries which amounts to 0.29. In NHS case, I assume that each consumer in i holds 10% of total wealth. The parameter α and μ are common to all consumers. I fit this specification to the data and estimate $\alpha = 0.915$ and $\mu = 0.065$. The rest of the solution algorithm is identical to the benchmark model.

Appendix B. 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 and per-capita GDP 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[40] are from the Penn World Tables Benchmark for 1996. 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 for the closest available year. Data on the distribution of income are from UN-WIDER World Income Inequality Database (WIID). The data on decile data sometimes vary in terms of their original sources and computation method. To minimise discrepancies I take the average across ten years (1991-2001) around the benchmark year and all available sources. If data for certain deciles were missing, they were imputed from Klaus and Squire (1996) and Milanovic and Yitzhaki (2001) using the closest available year. For few countries the data were imputed using regression of decile income on Gini coefficient and real per-capita GDP.

Appendix C. Extensions

Here I provide details on the equilibrium conditions and solution methods of the extensions of the model mentioned in the main text.

Monopolistic competition, Pareto Distribution and Quality

In section 5, I argued that the assumption of the Frèchet distribution is not central to the main results of the model. Here, I solve a version of the model using Pareto distribution of productivities. In addition, to show that the results are qualitatively robust to the exact specification of the productivity distribution and the production structure I solve a model that features monopolistic competition and Pareto distribution of productivities. This offers an advantage of considering endogenously determined measure of imported varieties which allows showing that the main results are insensitive to such an extension.

The set-up of the model and its solution largely follow Arkolakis, Demidova, Klenow and Rodriguez-Clare (2008) and Felbelmayr and Jung (2012). For simplicity, I consider a simple two-country, one-

[40]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.

sector general equilibrium model with endogenously determined wages and measure of operating firms. There is a fixed-cost that each firm has to pay, $w_j f_p$, before drawing its productivity distribution from Pareto distribution $F(q) = 1 - \left(\frac{q_{min}}{q}\right)^{\psi}$. There is an additional *market access* cost $w_j f_e$ for a firm to export from j to i. Prior to consumption all varieties are aggregated via CES function with parameter ϖ. This model can be solved using the following equilibrium conditions:

$$p_i = \left(\sum_k \frac{(\varpi_1 - 1)L_k}{\varpi f_p} \left(\frac{q_{min}}{q^*_{ik}}\right)^{\psi} \left(\frac{\varpi - 1}{\varpi} \frac{q^*_{ik}}{w_k \tau_{ik}}\right)^{\varpi - 1} \right)^{\frac{1}{1-\varpi}}; \tag{8.9}$$

$$\frac{f_p}{f_e} = (\varpi_1 - 1) \left(\frac{q_{min}}{q^*_{ii}}\right)^{\psi} \sum_k \left(\frac{q^*_{kk}}{q^*_{ki}}\right)^{\psi}; f_e = \frac{L_i w_i p_i^{\varpi-1}}{\varpi w_k} \left(\frac{\varpi - 1}{\varpi} \frac{q^*_{ki}}{w_k \tau_{ik}}\right)^{\varpi - 1}, \tag{8.10}$$

where $\varpi_1 = \frac{\psi}{\psi - (\varpi - 1)}$ which is assumed to be positive. The first equation is a simple identity of the aggregate price index. The remaining two equations are free-entry conditions and zero-profit conditions that can be solved for productivity cut-offs q^*_{ij}. These cut-off conditions can be used to calculated measure of imported variety from j to i as $(q^*_{ii}/q^*_{ij})^{\psi}$. I use the following parameterisation to simulate the model.

Table 7: Parameter values: CES and Pareto

Parameter	Country 1	Country 2	Parameter	Country 1	Country 2
q_{min}	0.5	0.5	ϖ	2	2
L	10	15	f_p	1	1
τ_{12},τ_{21}	1.5	1.5	f_e	1	1

Then, I artificially reduce trade costs τ_{12}, τ_{21} and calculate the outcome in terms of the price index for different values of ψ. I plot the results in Figure 11.

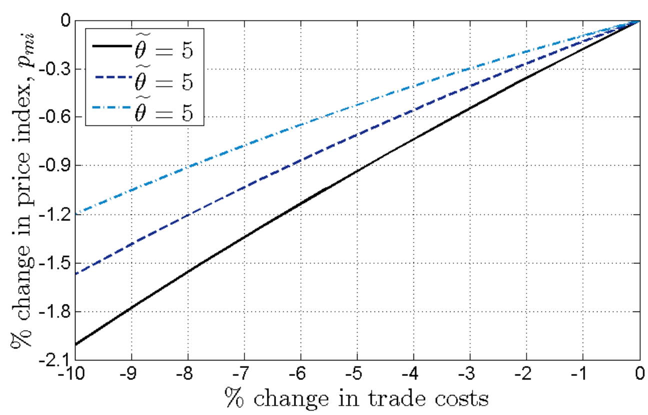

Figure 11: Trade liberalisation and Pareto Distribution

Figure 11 indicate the the main results of the benchmark model are robust to alternative distributional assumptions, production structure and/or endogenous measure of consumer varieties– the dispersion parameter still inversely determines the relative change in prices due to trade liberalization.

This model can be easily augmented to include quality as discussed in Section 7.2 of the main text where quality is determined by the productivity draw as $k(q) = q^{\varsigma}$. Then, the solution of the model (except for constants and power terms) is isomporhic to this version. To calculate the results for the quality model in the main text I use parameterisation as in Table 7 and set $\varsigma = 1.05$, $\sigma_m = \varpi$, $p_{mi} = p_i$ and $\widetilde{\theta} = \psi$.

Endogenous mark-ups

The solution of the model with endogenous mark-ups largely follows steps described in Simonovska (2010). Recall the pricing rule of a firm exporting from j to i:

$$p_{ij}(q) = \tau_{ij} w_i \left(\frac{1}{2q} + \frac{1}{2q_{ij}^*} \right). \tag{8.11}$$

Given behaviour of individual firms, the aggregate price index can be derived as follows:

$$P_i = \frac{2\psi + 1}{2\psi + 2} \frac{w_i}{q_{ii}^*} \left(\sum_k \frac{L_k}{(\psi + 1) f_e} \left(\frac{q_{min}}{q_{ik}^*} \right)^{\psi} \right). \tag{8.12}$$

The remaining equilibrium conditions (as in the previous section) are derived using zero-profit and free-entry conditions:

$$\frac{\psi + 1}{\psi + 2} = \frac{v_{2m} w_i q_{ij}^*}{w_j \tau_{ij}} + \left(\frac{q_{min}}{q_{ij}^*} \right)^{-\psi} \frac{2 v_{1m} (\psi + 1)^2 f_e w_i q_{ij}^*}{(\tau_{ij} w_j)^{\psi + 1} \sum_k L_k (\tau_{ik} w_k)^{-\psi}}; \tag{8.13}$$

$$w_i = \left(\sum_j \frac{L_j w_j}{\tau_{ji}^{\psi} \sum_k (\tau_{jk} w_k)^{-\psi}} \right)^{\frac{1}{\psi+1}}. \tag{8.14}$$

As in the previous section, I parameterise the model for two asymmetric countries using values reported in 8. I rename ψ as $\widetilde{\theta}$ and simulate the model using different values thereof. The simulation results presented in the main text also suggest that the main intuition of the benchmark model is robust to this extension.

Table 8: Parameter values: VES model

Parameter	Country 1	Country 2	Parameter	Country 1	Country 2
q_{min}	0.5	0.5	v_{1m}	0.8	0.8
L	10	15	v_{2m}	0.4	0.4
τ_{12},τ_{21}	1.5	1.5	f_p	0	0
f_e	1	1			