On Measuring the Welfare Gains from Trade under Consumer Heterogeneity

Sergey Nigai*
ETH Zurich
June, 2012

Abstract

I develop a multi-country model of international trade with heterogeneous consumers and non-homothetic preferences. I use the model to quantify the bias in the conventional estimates of gains from trade calculated under the assumption of a representative consumer. The model predicts heterogeneous income and price effects that are translated into consumer-specific welfare gains and further quantified in a counterfactual trade liberalization experiment. I find that conventional measures, such as the average real income per capita, are adequate welfare measures mostly for consumers in the right tail of the income distribution. This measure overestimates the gains from global trade liberalization by up to 9% and 88% for the median and the poorest consumer, respectively. In terms of the aggregate country-level welfare gains, the measurement error is between -6% and 8% in the utilized experiment.

Keywords: International trade; Income distribution; General equilibrium model.

JEL-codes: F11; F14; Q43; Q48.

*ETH Zurich, Weinbergstrasse 35, 8092 Zurich, Switzerland; E-mail: nigai@kof.ethz.ch; Telephone: +41 44 632 9360
1 Introduction

An overwhelming majority of economists believe that free international trade is welfare enhancing. In fact, this conventional wisdom may have been the least disputable one in the profession. The general public, however, seems to have mixed feelings towards globalization, with many people consistently opposing free trade policies. Surveys often indicate that up to half of the population views free trade as potentially harmful. What is the reason for this large gap between one of the most robust theoretical and empirical results in economics and general perception of the public?

I argue that the reason for this disparity stems from the assumption of a representative consumer. I show that this assumption is a source of large measurement errors in the estimates of welfare gains from trade for certain consumer groups. For that, I build a multi-country model of trade with non-homothetic preferences and heterogeneous consumers, and demonstrate that welfare gains from trade in a counterfactual global trade liberalization experiment largely differ both qualitatively and quantitatively across individuals.

The model predicts that under trade liberalization different consumer groups experience heterogeneous changes in their total nominal incomes and consumer price indices. This heterogeneity must be taken into account when evaluating welfare gains because measures based on aggregate income and aggregate price indices, such as average real income per capita, may (under)overstate gains from trade by up to (13%) 88% depending on the consumer group and the country. In terms of aggregate welfare, the differences between changes in average real income per capita and changes in true aggregate gains are between -6% and 8%.

Differences in the consumption patterns across consumers are the first source of heterogene-

---

1 The survey data among economists across different periods show that on average only about 5% of economists believe that tariffs do not reduce welfare. See Alston, Kearl and Vaughan (1992), Poole (2004) and others.

2 According to the survey conducted by the Pew Research Center in 2010, only 35% of respondents agreed that free trade agreements such as NAFTA and WTO policies are good for the United States. In fact, 44% of the respondents indicated that they consider free trade agreements to be bad for the United States.
ity in welfare gains from trade. The poor and the rich consume different bundles of goods. For example, an abolishment of import tariffs on luxury cars and premium wines will have positive price effects on the rich, but will offer no gains to the poor, whose consumption baskets do not include those goods. The non-homothetic preference structure that I employ here allows calculating unique price indices based on the expenditure shares of each individual. I use these price indices to deflate the nominal income of each consumer and calculate adequate estimates of the welfare gains.

Consumers also differ in terms of their nominal incomes. I assume that each country has a unique distribution of physical capital, so that the factor returns are distributed unevenly across individuals. On the other hand, total government transfers such as foreign aid and tariff revenues are distributed equally among all consumers. Trade liberalization affects factor prices and government transfers which exert heterogeneous income effects. Depending on the relative shares of factor returns and government transfers in total income, each consumer faces a potential trade-off between change in factor prices and the size of tariff revenues in case of a trade liberalization.

Recently, non-homothetic preferences have been reintroduced into the models of international

---

3Fajgelbaum, Grossman and Helpman (2011) formulate a model with non-homothetic preferences, horizontal and vertical product differentiation. They show that income distribution, in terms of the numeraire good, remains unchanged after a trade liberalization episode but not in terms of real consumption. Two empirical case studies discuss the bias from calculating welfare gains using a price index common to all consumers. Porto (2006) calculates welfare gains for different consumer groups in Argentina from joining MERCOSUR. Recently, Broda and Romalis (2009) have argued that welfare gains for low-income groups in the US have been underestimated by using the price index of a representative consumer. The authors also argue that around 50% of the documented increase in income inequality in the US between 1994 and 2005 is due to the problem of using a uniform price index.

4Another way to introduce heterogeneity in incomes is to account for heterogeneous wages associated with heterogeneous profits across firms in the presence of labor market frictions (see Egger and Kreickermeier, 2009; Helpman, Itskhoki and Redding, 2010; Davis and Harrigan, 2011 and others). For example, Davis and Harrigan (2011) introduce labor market frictions into Melitz (2003) model and show while trade liberalization raises the average wage in their model, it negatively impacts workers that had relatively high wages in the pre-trade equilibrium. Several empirical studies point to the heterogeneous income effects from trade liberalization. Artuc, Chaudhuri and McLaren (2010) use a dynamic labor adjustment model and estimate how trade liberalization affects different types of workers. McLaren and Hakobyan (2010) use US Census data to estimate local welfare effects for heterogenous workers from joining NAFTA. 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.
trade (for example see Markusen, 2010; Simonovska, 2010; Fieler, 2011). The authors show that non-homotheticity plays an important role in explaining bilateral trade patterns across several margins. However, these papers are mainly concerned with consumer heterogeneity across countries and not within a single country. In that sense, they still evaluate potential welfare gains through the lens of a representative consumer which, as I argue, can be a source of large bias.

I recognize the importance of large differences in the consumption patterns across countries in explaining bilateral trade flows. I also add an additional dimension – differences in the consumption patterns within a single country. Besides identifying differences in welfare gains from trade of consumers within each country, this approach also delivers quantitative predictions documented in the empirical literature but currently missing in computable general equilibrium work. The model provides the missing two-way link between international trade and within-country income inequality (for example see Goldberg and Pavcnik 2004, 2007; Harrison, McLaren and McMillan, 2010). On the one hand, the distribution of income shapes import demand schedules, so that developing countries with relatively high income inequality and low average income are likely to import a higher share of manufacturing goods than countries with low income inequality and low average income. On the other hand, trade liberalization raises income inequality through heterogeneous income and price effects on average.

In the next section, I illustrate the fundamental problem with current approaches that quantify welfare gains using aggregate measures such as average real income per capita. I present the model in Section 3. In Section 4, I estimate the parameters of the model and describe the calibration procedures. Section 5 discusses novel predictions of the model that are consistent with a number of empirically established facts. I conduct a counterfactual trade liberalization experiment to assess the validity of conventional welfare metrics and evaluate consumer-specific welfare gains in Section 6. The last section offers a brief conclusion.
2 Consumer heterogeneity and measures of welfare

Let \( d = 1, \ldots, D \) denote the type of consumer in country \( i \) and let \( Y_{id} \) denote his total nominal income. Suppose there are \( g = 1, \ldots, G \) different goods available for consumption. Let \( s_{g, id} \) be the share of income that consumer \( d \) spends on good \( g \), so that \( \sum_{g=1}^{G} s_{g, id} = 1 \). The shares \( s_{g, id} \) vary across consumers and depend on the individual income level \( Y_{id} \). For example, poor consumers spend a larger share of their income on food relative to rich consumers. The welfare of consumer \( d \) in country \( i \) is then measured as:

\[
\omega_{id} = \frac{Y_{id}}{P_{id}}, \text{ where } P_{id} = \Pi_{g=1}^{G} p_{gi}^{s_{g, id}}.
\] (2.1)

Here, \( P_{id} \) is \( d \)'s price index calculated using a country-specific vector of prices \( p_{gi} \) and consumer-specific expenditure shares \( s_{g, id} \).

Next, consider the average real income per capita:

\[
\bar{y}_i = \frac{\bar{Y}_i}{P_i}, \text{ where } \bar{Y}_i = \frac{1}{L_i} \sum_{d=1}^{D} Y_{id} \text{ and } P_i = \Pi_{g=1}^{G} p_{gi}^{s_{gi}}.
\] (2.2)

Here, \( L_i \) is the total number of consumers in \( i \) and \( s_{gi} \) is the country-specific expenditure share on good \( g \). Two sources of the measurement error about welfare in models assuming homogenous consumers are immediately clear. First, under consumer heterogeneity average nominal income \( \bar{Y}_i \) differs from individual total income \( Y_{id} \). Second, depending on the level of income, consumer \( d \)'s expenditure shares \( s_{g, id} \) also deviate from country-level expenditure shares \( s_{gi} \).

Let me define the measurement error \((me_{id})\) for consumer \( d \) in \( i \) as follows:

\[
me_{id} \equiv 100 \times \left( \frac{\bar{y}_i}{\omega_{id}} - 1 \right) = 100 \times \left( \frac{Y_{id}}{\bar{y}_i} \frac{P_i}{P_{id}} - 1 \right).
\] (2.3)

\(^5\)Broda, Leibtag and Weinstein (2009) discuss the importance of using consumer-type specific price indices such as \( P_{id} \) here.
Here, $me_{id}$ measures by how much (in percent) $\bar{y}_i$ overestimates true welfare of consumer $d$. It is clear from [2.3] that $me_{id}$ will be especially high for consumers whose income deviates relatively more from the mean and for countries with higher income inequality across different $d$'s. In a representative consumer framework $Y_{id} = \bar{Y}_i$ and $P_{id} = P_i$, so that [2.3] collapses to $me_{id} = 0$. This is assumed in conventional models of trade. It turns out that the model used in this paper suggests that the range and the mean of $me_{id}$ are extremely large. Hence, if one evaluates welfare gains from trade liberalization without accounting for consumer heterogeneity, one will overestimate the gains for some consumers and underestimate them for others. For instance, rich consumers would benefit if trade liberalization led to a reduction in prices of luxury goods. On the other hand, poor consumers would not gain much because they do not consume any luxury goods in the first place. However, looking at the reduction in a common price index driven solely by the decrease in the price of luxury goods, one may wrongly conclude that trade liberalization is beneficial for all consumers. The measurement errors in terms of quantified aggregate gains from trade are also large.

I use a general equilibrium model of trade calibrated to real data on $Y_{id}$ and $P_{id}$ and show that under a counterfactual trade liberalization $me_{id}$'s are very large, especially for consumers in the left tail of the income distribution.

3 Model

The production side of the model is in the spirit of Eaton and Kortum (2002). There are $N$ countries in the world. Each country $i = 1 \ldots N$ is endowed with $L_i$ units of labor and $K_i$ units capital. Each country hosts a measure of heterogeneous firms in three sectors: agricultural, manufacturing and non-tradable. Manufacturing and agricultural goods can be traded subject to sector-specific iceberg trade costs from country $n$ to country $i - \tau_{m,in}$ and $\tau_{a,in}$ respectively. The factors of production are assumed to be completely mobile across

---

6 The usual triangularity (non-arbitrage) assumption applies.
sectors but not countries.

I introduce consumer heterogeneity in the spirit of Mayer (1984) by assuming that each household owns a unit of labor and \( d \) units of capital.\(^7\) Households vary according to their endowment of capital and can be of type \( d = 1, \ldots, D \). Here, \( d \) stands for the \( d \)-th decile in the capital distribution.\(^8\) The distribution of capital is assumed to be exogenous, stationary, and country-specific. Hence, households are homogeneous within a decile in any country \( i \) but not across countries and/or deciles.

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

A large class of general equilibrium models of trade deliver identical predictions in terms of welfare gains from trade (see Arkolakis, Costinot and Rodriguez-Clare, 2010). The two necessary conditions for this remarkable result are a CES demand system and a structural gravity equation. This model deviates in two major ways from such an approach: 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 quantitative insights about the welfare gains from trade liberalization at both individual and aggregate levels.

\(^7\)There are alternative ways to introduce heterogeneity in workers. Differences in abilities (Blanchard and Willmann, 2011), skill intensities (Costinot and Vogel, 2010) or distribution of human capital endowments (Bougheas and Riezman, 2007) are all viable options. The solution of the model does not depend on the interpretation of capital, \( k_{id} \). Here, I interpret capital as physical capital without loss of generality.

\(^8\)I use deciles to approximate the distribution of capital simply because no data are available on a more disaggregated level. On the other hand, I find that using less disaggregated measures such as quartiles or quintiles would convolute the differences between the poor and the rich to the point when income inequality is no longer as important (for example see Fieler, 2011).
3.1 Households

Households of type $d$ in country $i$ maximize consumption of the non-tradable good, $c_{ni}$, the tradable manufacturing good, $c_{mi}$, and the tradable agricultural good, $c_{ai}$, according to the following nested Stone-Geary utility function:

$$U = \left( \frac{c_{ni}}{c_{mi}} \right)^{1-\beta} (c_{ai} - \mu)^{1-\alpha} \text{ s.t. } y_{id} = c_{ni}p_{ni} + c_{mi}p_{mi} + c_{ai}p_{ai},$$  \hspace{1cm} (3.1)

where $p_{ni}$, $p_{mi}$, and $p_{ai}$ are prices of the non-tradable, manufacturing, and agricultural goods, respectively. Let me denote labor as $l_i$ and capital as $k_i$, then total per-capita income of a household of type $d$ in $i$ is $y_{id} = (l_iw_i + k_idr_i) + v_i$, where $w_i$ is the wage rate, $r_i$ is the capital rental rate, and $v_i$ are total per-capita transfers.\footnote{9} The utility function in (3.1) captures non-homotheticity of preferences through the term $\mu$, which can be interpreted as a subsistence level of income\footnote{10} As long as $y_{id} > \mu p_{ai}$ the value of final demands of type-$d$ consumers in country $i$ are given by:

$$c_{ai,d}p_{ai} = (1 - \alpha)y_{id} + \alpha\mu p_{ai},$$  \hspace{1cm} (3.2)

$$c_{ni,d}p_{ni} = \alpha\beta(y_{id} - \mu p_{ai}),$$  \hspace{1cm} (3.3)

$$c_{mi,d}p_{mi} = \alpha(1 - \beta)(y_{id} - \mu p_{ai}),$$  \hspace{1cm} (3.4)

and $c_{ni,d}p_{ni} = c_{mi,d}p_{mi} = 0$, and $c_{ai,d}p_{ai} = \frac{y_{id}}{p_{ai}}$ whenever $y_{id} \leq \mu p_{a}$. The demand equations in (3.2)-(3.4) can be normalized by total income of consumers of type $d$ to get expenditure shares in that decile. For instance, consumer of type $d$ in country $i$ spends $s_{ai,d} \equiv \frac{c_{ai,d}p_{ai}}{y_{id}}$ on agricultural goods.

For a given distribution of $y_{id}$, I also derive country-level income shares spent on non-
tradables, tradables and agricultural goods – $s_{ni}$, $s_{mi}$, and $s_{ai}$ – respectively, which are defined as follows:

$$s_{ni} = \frac{\sum_{d=1}^{D} c_{ni,d}p_{ni}}{\sum_{d=1}^{D} y_{id}}; \quad s_{mi} = \frac{\sum_{d=1}^{D} c_{mi,d}p_{mi}}{\sum_{d=1}^{D} y_{id}}; \quad s_{ai} = \frac{\sum_{d=1}^{D} c_{ai,d}p_{ai}}{\sum_{d=1}^{D} y_{id}},$$

(3.5)

Let me also define $\bar{y}_i = \frac{1}{D} \sum_{d=1}^{D} y_{id}$ as the average level of real income per capita. This will turn out to be useful in subsequent sections.

### 3.2 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. This allows me to provide clear quantitative predictions in the counterfactual section that have straightforward interpretations relative to the benchmark data.

Each country is endowed with a fixed measure of capital and labor. Besides these two factors of production, firms in all sectors 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. This way of modeling sectoral production is consistent with the data in input-output tables.

### Non-tradable sector

Let $n_i$ be the output of the non-tradable good, $m_i$, the quantity of the manufacturing ag-

---

11 Although, the model here departs from the conventional Ricardian models in terms of consumer heterogeneity and non-homothetic preferences, the production structure specified here is identical to the one specified in Eaton and Kortum (2002).

12 For example, see Alvarez and Lucas (2007) or Egger and Nigai (2012).

13 Consistent with the literature and the OECD classification I classify industries in three broad sectors: Agricultural goods, Manufacturing goods and Non-tradable goods. The SDS aggregates are produced according to a conventional CES technology with the elasticity parameters $1 - \sigma_a$ and $1 - \sigma_m$ for the agricultural and manufacturing sectors respectively.
aggregate and $a_i$, the quantity of the agricultural aggregate. I assume that each country has a unit measure of firms in the non-tradable sector producing identical non-tradable output using constant-returns-to-scale technology:

$$n_i = \left( l_i^\nu k_i^{1-\nu} \right)^\phi (n_i^\rho m_i^{1-\rho})^{1-\phi}, \quad (3.6)$$

accordingly the price of the non-tradable good is:

$$p_{ni} = \Gamma_n (w^\nu r_i^{1-\nu})^\phi (p^\rho p_{mi}^{1-\rho})^{1-\phi}, \quad (3.7)$$

where $\Gamma_n$ is a sector-specific constant.

**Manufacturing sector**

Each country hosts a measure of firms each producing a unique variety with a productivity drawn from a Fréchet distribution. The productivity is a realization of a random variable $z_{mi}$ distributed according to:

$$F_{mi}(z_{mi}) = \exp(-\lambda_{mi} z_{mi}^{-\theta_m}), \quad (3.8)$$

where $\lambda_{mi}$ is a country-specific productivity parameter and $\theta_m$ is a dispersion parameter which is common across all countries. Each firm in the sector employs labor, capital, non-tradable and manufacturing aggregates in the following way:

$$m_i(q) = z_{mi}(q) (l_i^\nu k_i^{1-\nu})^\xi (n_i^\rho m_i^{1-\rho})^{1-\xi}, \quad (3.9)$$

where $q$ denotes different varieties of the manufacturing goods. The probabilistic representation of technologies allows me to derive the average variable cost of a producer of a manufacturing variety in country $i$: 10
\[ \kappa_{mi} = \Gamma_m \lambda_{mi}^{-\theta_m} (w_i^\nu \epsilon_i^1 \nu^1) \xi (p_{mi}^1 \epsilon_{mi}^1)^{1-\xi} \],

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

\[ p_{mi} = \left( \sum_{\ell} \left( \kappa_{\ell} \tau_{m,ij} t_{m,ij} \right) \right)^{-\frac{1}{\theta_m}}. \]

(Agricultural sector)

Similar to the firms in the tradable sector, firms in the agricultural sector each produces a unique variety with a total factor productivity parameter drawn from a country-specific productivity distribution:

\[ F_{ai}(z_{ai}) = \exp(-\lambda_{ai} z_{ai}^{-\theta_i}). \]

The respective expression of the production function of a producer of an agricultural variety \( h \) in \( i \) is:

\[ a_i(h) = z_{ai}(h) (k_i^\nu k_i^1 \nu^1)^\gamma (n_i^m m_i^\epsilon a_i^1 \epsilon^\gamma)^{1-\gamma}. \]

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. This modeling choice is consistent with the data on the production inputs in the three sectors. The price of the agricultural aggregate can be expressed using

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

\[ \text{This approach is consistent with Caliendo and Parro (2011) who use input-output tables to account for the inter-dependence of industries. My formulation uses information from the input-output tables in a similar way but on a more aggregate level.} \]
average variable cost in i’s partner countries, $\kappa_{an}$, iceberg trade costs specific to that sector, $\tau_{a,in}$, and an import tariff $t_{a,in}$:

$$p_{ai} = \left( \frac{N}{\sum_{\ell} (\kappa_{a\ell}\tau_{a,i\ell}t_{a,\ell})^{\theta_a}} \right)^{-\frac{1}{\theta_a}}. \quad (3.14)$$

### 3.3 International trade

International trade occurs in the manufacturing and agricultural sectors. Firms producing identical varieties in different countries compete vis-à-vis each other given geographical and policy barriers to trade. The probabilistic representation of technologies permits the derivation of trade shares in a straightforward way:

$$x_{m,in} = \frac{(\kappa_{mn}\tau_{m,in}t_{m,in})^{-\theta_m}}{\sum_{\ell} (\kappa_{m\ell}\tau_{m,i\ell}t_{m,\ell})^{-\theta_m}}, \quad \text{and} \quad x_{a,in} = \frac{(\kappa_{an}\tau_{a,in}t_{a,in})^{-\theta_a}}{\sum_{\ell} (\kappa_{a\ell}\tau_{a,i\ell}t_{a,\ell})^{-\theta_a}} \quad (3.15)$$

Trade shares, however, are not sufficient to close the model. It is necessary to derive total spending of each country on both manufacturing and agricultural goods and specify the market clearing conditions. To do this I derive i’s total absorption capacities of manufacturing and agricultural goods, respectively. Let $Y_{ni}$, $Y_{mi}$, and $Y_{ai}$ be the total sectoral output of the non-tradable, manufacturing, and agricultural goods, respectively, and let $D_{ni}$, $D_{mi}$, $D_{ai}$ be net imports in the respective sectors. Consistent with Bernand, Eaton, Jensen and Kortum (2003), I define total absorption in a sector as total output plus net imports. The absorption, however, is nothing but the sum of intermediate and final demands. Hence, the following identity must hold:

$$\begin{pmatrix} Y_{ni} \\ Y_{mi} \\ Y_{ai} \end{pmatrix} + \begin{pmatrix} D_{ni} \\ D_{mi} \\ D_{ai} \end{pmatrix} = \begin{pmatrix} (1-\phi)\rho & (1-\phi)(1-\rho) & 0 \\ (1-\xi)\zeta & (1-\xi)(1-\zeta) & 0 \\ (1-\gamma)\epsilon & (1-\gamma)\rho & (1-\gamma)(1-\epsilon-\rho) \end{pmatrix} \begin{pmatrix} Y_{ni} \\ Y_{mi} \\ Y_{ai} \end{pmatrix} + \begin{pmatrix} s_{ni} & 0 & 0 \\ 0 & s_{mi} & 0 \\ 0 & 0 & s_{ai} \end{pmatrix} \begin{pmatrix} Y_i \\ Y_i \\ Y_i \end{pmatrix}, \quad (3.16)$$

here $Y_i$ is total income of consumers in $i$. Let $f_{ni}$, $f_{mi}$ and $f_{ai}$ be the ratio of the absorption
capacities of the non-tradable, manufacturing and agricultural sectors, respectively, to total expenditures in $i$, then (3.16) can be reformulated as follows:

$$
\begin{pmatrix}
Y_{ni} \\
Y_{mi} \\
Y_{ai}
\end{pmatrix} +
\begin{pmatrix}
D_{ni} \\
D_{mi} \\
D_{ai}
\end{pmatrix} =
\begin{pmatrix}
f_{ni} & 0 & 0 \\
0 & f_{mi} & 0 \\
0 & 0 & f_{ai}
\end{pmatrix}
\begin{pmatrix}
Y_{i} \\
Y_{i} \\
Y_{i}
\end{pmatrix}.
$$

(3.17)

Here $f_{ni}$, $f_{mi}$ and $f_{ai}$ are functions of production parameters, sectoral trade imbalances, and country-level consumption shares, defined by consumption shares of consumers of each type $d$ in $i$. The latter depend on both the average level of income per capita and the level of income in different deciles in each country.

To close the model, I assume that total imports, $IM_{i}$, equal total exports, $EX_{i}$ up to a country-specific constant $D_{i}^{16}$

$$
D_{i} = EX_{i} - IM_{i}, \text{ where }
$$

(3.18)

$$
IM_{i} = (L_{wi} + K_{ri} + L_{vi}) \sum_{n=1}^{N} (f_{mi}x_{m,in} + f_{ai}x_{a,in}),
$$

(3.19)

$$
EX_{i} = \sum_{n=1}^{N} (L_{ni}w_{n} + K_{ri}r_{n} + L_{ni}v_{n}) (f_{mi}x_{m,ni} + f_{ai}x_{a,ni}).
$$

(3.20)

The central difference of (3.18) from the Ricardian models with homothetic preferences and/or homogeneous consumers is in terms $f_{mi}$ and $f_{ai}$. In those models, the shares are assumed to be constant across all countries and consumers. On the contrary, here $f_{mi}$ and $f_{ai}$ can be viewed as a link between the non-homotheticity of preferences, consumer heterogeneity, and total import demand.

---

16Closing the model in this way is in the spirit of Dekle, Eaton and Kortum (2007), where $D_{i}$ is an exogenous deficit constant observed in the data.
4 Calibration

I calibrate the model to 92 countries in the world\textsuperscript{17} The reference year for all the data is 1996. I describe the data sources in the Appendix.

For the counterfactual experiment I need to calibrate the parameters of the utility function and the production functions in the three sectors. I also need to estimate $\theta_m$ and $\theta_a$. I solve for the counterfactual values in the spirit of Dekle, Eaton and Kortum (2007) and do not have to estimate $\lambda_{mi}$, $\lambda_{ai}$, $\tau_{m,in}$, and $\tau_{a,in}$ since those are taken as primitives (constants) in the model.

4.1 Parameters of the utility function

Calculating $\beta$, which governs the ratio of the consumption of non-tradable to manufacturing goods, is straightforward given the data on households’ spending. This share is constant across countries and does not vary much with the average level of per-capita income. This is confirmed in the left panel of Figure\textsuperscript{1} where I plot the ratio of the total non-tradable consumption in each country to the total manufacturing consumption. It is then straightforward to infer the value of $\beta$ from the following:

$$ \frac{\beta}{1 - \beta} = \frac{1}{N} \sum_{i=1}^{N} \frac{p_{mi}}{p_m} \sum_d c_{ni,d} \sum_{i=1}^{N} \frac{c_{mi,d}}{c_{mi,d}} $$

(4.1)

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

Estimating the remaining two parameters $\alpha$ and $\mu$ is more challenging because, unlike $\beta$, the share of income spent on agricultural goods is not constant across countries and is consistently

\textsuperscript{17}The limitations of the data do not allow me to extend the sample further. However, the 92 countries in the sample include all large countries in the world. Hence, the calibrated model is very close to reflecting the world in economic terms. The sum of GDP’s of the 92 countries in the sample constituted to about 93\% of total world GDP in 1996.
correlated with real income of an average household in country $i$. The relationship\textsuperscript{18} is seemingly non-linear as shown in the right panel of Figure 1 where I plot the ratio of total consumption in agricultural goods to the remaining expenditures.

![Figure 1: Expenditure Ratios versus real Average Real Income per Capita](image)

The reason for this strong relationship is the non-homotheticity of household preferences. This has been well documented in the literature\textsuperscript{19} Modeling this relationship using Stone-Geary preferences has two advantages. First, the utility function leads to tractable linear demand functions. Second, the parameters of the utility function have straightforward and intuitive interpretation\textsuperscript{20}

Calibrating $\alpha$ and $\mu$ is a non-standard optimization problem. To estimate these parameters, I minimize the squared distance between country-level expenditure shares predicted by the model as described in (3.5) in Section 3.1.

\textsuperscript{18}This is the maximum number of observations of the data in Penn World Tables. Benchmark year 1996.

\textsuperscript{19}Fieler (2010) introduces non-homothetic preferences into a Ricardian Eaton-Kortum type model. Simonovska (2010) links non-homotheticity to the concept of pricing to market using a unique dataset for the OECD countries. Markusen (2010) demonstrates that non-homothetic preferences can resolve many puzzles of international economics.

\textsuperscript{20}Tombe (2012) uses Stone-Geary preferences to explain trade patterns in food products between poor and rich countries. A minor departure of this paper from the literature is in the specification of the utility function – a nested functional form which is easier to calibrate and interpret.
$$\min_{\alpha, \mu} \sum_{i=1}^{N} (s_{ai} - s_{ai}(\alpha, \mu))^2 \text{ s.t. } \alpha \in [0, 1],$$  \hspace{1cm} (4.2)

where $s_{ai}$ are the data and $s_{ai}(\alpha, \mu)$ is the function of $\alpha$ and $\mu$, which given the value of $\beta$ and the data on $y_{id}$ and $p_{ai}$, is calculated as in (3.5). Solving (4.2) yields $\alpha = 0.8860$ and $\mu = 0.0017$. The fit of calibration is good, the correlation between the predicted and actual $s_{ai}$ is $0.92$\textsuperscript{21}.

### 4.2 Parameters of the production functions

The only parameter common to all three production functions is the capital-labor ratio parameter $\nu$. Consistent with the literature in macroeconomics and international trade (for example, see Gollin, 2002), I set $\nu = 0.67$.

The rest of the production parameters are calculated using input-output tables as follows. The 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, the parameters $\{\varrho, \zeta, \epsilon, \rho\}$ are calculated from the ratio of total non-tradable input to total manufacturing input. Cross-country averages and standard deviations of the production parameters are provided in Table 1.

\begin{table}[h]
\centering
\begin{tabular}{|c|cccccc|}
\hline
 & $\phi$ & $\xi$ & $\gamma$ & $\varrho$ & $\zeta$ & $\epsilon$ & $\rho$ \\
\hline
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 \\
\hline
\end{tabular}
\caption{Production parameters}
\end{table}

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

I estimate the trade elasticities in the manufacturing and the agricultural sectors – $\theta_m$ and

\textsuperscript{21}For this calibration exercise and throughout the rest of this paper, all income values are normalized such that the average real income per capita in the USA is unity.
\( \theta_a \) using the data on trade flows and tariffs. Let \( X_{m,in} \) denote manufacturing trade flow from \( n \) to \( i \). Normalize trade flows by the value of domestic sales to get a familiar structural gravity equation:

\[
\frac{X_{m,in}}{X_{m,ii}} = \left( \frac{\kappa_n \tau_{m,in} t_{m,in}}{\kappa_i} \right)^{\theta_m} \text{ where } \tau_{m,in} = (\tau_{m,i} \tilde{\tau}_{m,in} \tau_{m,n}). \tag{4.3}
\]

I assume total trade costs \( \tau_{m,in} \) to be log-additive with tariffs and consist of an exporter-specific asymmetric component – \( \tau_{m,n} \), an importer specific asymmetric component – \( \tau_{m,i} \), and a symmetric component \( \tilde{\tau}_{m,in} \). Consistent with the literature, I proxy for the symmetric component of trade costs \( \tilde{\tau}_{m,in} \) using a distance measure and an adjacency dummy. The two asymmetric trade cost components will be captured by respective country-specific fixed effects. I estimate the following stochastic version of (4.3):

\[
\frac{X_{m,in}}{X_{m,ii}} = \exp[\log(ex_n) + \log(im_i) - \theta_m \log(t_{m,in}) - \theta_m \log(\tilde{\tau}_{m,in})] + error_{in}, \tag{4.4}
\]

where \( im_i \) and \( ex_n \) are catch-all importer and exporter fixed effects, respectively. Notice that the coefficient on tariffs between \( i \) and \( n \) identifies \( \theta_m \). I estimate \( \theta_a \) using data on \( X_{a,in} \) and \( t_{a,in} \) in the same fashion. I chose to estimate (4.4) in levels rather than in logs to avoid the problem of zeros. The trade data for the 92 countries include a considerable number of zeros and dropping those may lead to inconsistent marginal effects. In practice, I maximize the respective Poisson Pseudo Maximum Likelihood function as advocated by Santos Silva and Tenreyro (2006). The estimates are \( \hat{\theta}_m = 6.53(1.23) \) and \( \hat{\theta}_a = 12.07(1.16) \).

---

22 The coefficients on distance and adjacency variables have the expected signs and due to the solution strategy are of no particular interest, hence not reported.

23 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. For example see Donaldson, Costinot and Komunjer (2012).

24 For example, see Baldwin and Harrigan (2011) or Chor (2010).

25 Standard errors in parenthesis are based on Eicker-White sandwich estimates and are robust to heteroskedasticity of an unknown form.
The values of $\theta_m$ and $\theta_a$ suggest that differences in technology and factor prices are relatively larger and more important for trade in the agricultural sector. This is consistent with Tombe (2012) who points out that the productivity gap between rich and poor countries is especially pronounced in agriculture.

4.3 Benchmark distribution of capital

I use the data on the distribution of income to calibrate the model to the observed levels of heterogeneity across consumers. The benchmark level of real income is:

$$y_{id} = (l_iw_i + r_ik_{id}) + v_i, \quad (4.5)$$

here capital ownership, $k_{id}$, is the only source of heterogeneity. Total government transfers, $v_i$ include foreign aid, credits and tariff revenues. I calculate $v_i$ as the sum of the current account balance (net of trade deficit) and tariff revenues given benchmark levels of tariffs $t_{m,in}$ and $t_{a,in}$. I, then, use the data on the income distribution in each country to pin down the values of $k_{id}$.

5 Predictions of the model

General equilibrium models of trade often fail to predict two stark relationships between trade and income that are evident in the data: (i) trade increases in income per capita, and (ii) trade and within-country income inequality are correlated. Many recent papers have tackled the former issue by incorporating non-homothetic preferences into trade models. My approach is consistent with previous work and provides predictions in line with the data. The latter issue, however, has been largely ignored in general equilibrium analysis of trade.

\footnote{All values here are in real terms per capita.}
Numerous empirical studies have suggested that trade liberalization episodes have been characterized by a substantial increase in income inequality. For an excellent overview of recent advances in the research of trade and inequality refer to Goldberg and Pavcnik (2004, 2007). In addition, a number of empirical papers have found a considerable amount of evidence in support of Linder’s (1961) hypothesis – countries with similar income distributions tend to trade more. I introduce within country differences in capital owned by households, which, together with a non-homothetic preference structure, link income inequality to total import demand. The model delivers predictions in line with the empirical findings on trade and income inequality.

5.1 Trade and per-capita income

It is a well established fact that total bilateral trade increases with per capita incomes of both exporter and importer. Hence, it is essential for a model to provide clear-cut predictions with respect to this relationship. Fieler (2011) criticizes conventional trade models because they predict that trade increases in total income, regardless of the distribution of population relative to average income. On the other hand, the data suggest that trade increases in real income per capita rather than population. The model here captures this feature of the data well and is not subject to Fieler’s critique.

To illustrate that the model does provide predictions consistent with empirical findings consider the following. Recall that $X_{m,in}$ and $X_{a,in}$ are total trade flows from $n$ to $i$ in manufacturing and agricultural goods, respectively. These can be decomposed into the supply and demand effects.

$$X_{m,in} = \underbrace{x_{m,in}}_{\text{supply side}} \times \underbrace{f_{mi}}_{\text{expenditure share}} \times \underbrace{Y_i}_{\text{market size}},$$  \hspace{1cm} (5.1)
and a similar expression for $X_{a,in}$. Notice that $x_{m,in}$ depends only on technology and relative factor prices, and is independent of the structure of preferences. However, $f_{mi}$, the share of aggregate expenditure $Y_i$ spent on tradables depends on $s_{mi}$\textsuperscript{27}. To see the argument in a simple way assume that $y_{i,d} > \mu p_a$ for all $d$. Then we can decompose total bilateral imports of $i$ from $n$ from (5.1) as follows:

$$X_{m,in} = \Phi x_{m,in} \times \frac{\sum_{d=1}^{D} L_{id}(y_{id} - \mu p_{ai})}{\sum_{d=1}^{D} L_{idyid}} \times \sum_{d=1}^{D} L_{idyid} = \Phi x_{m,in} \times L_i \times (\bar{y}_i - \mu p_{ai}),$$

(5.2)

where $\Phi$ is a constant. The model predicts that bilateral imports $X_{m,in}$ are increasing in average real income per capita, $\bar{y}_i$ faster than in the population $L_i$, \textit{ceteris paribus}. The same holds for trade flows in agricultural goods.

### 5.2 Income inequality and trade

Trade models based on the assumption of a representative consumer fail to capture the strong link between the income distribution and international trade. A number of empirical papers (for example, see Bernasconi, 2011) have found strong evidence of a correlation of within-country income distribution similarities across countries and bilateral trade. This goes back to Linder’s (1961) hypothesis of overlapping demands. The present model delivers predictions consistent with that hypothesis.

For simplicity, in (5.2) I reduced total country demand to a function of total population, average income per capita and prices. To do that I assumed that $y_{i,d} > \mu p_{ai}$ for all $i, d$. Of course, in reality $y_{id} \leq \mu p_{ai}$ for some $i, d$. This is where the distributional effects begin to matter.

Suppose, I endowed \textit{all} countries in the world with the distribution of capital observed in the United States while keeping the average level of real income per capita unchanged. If

\textsuperscript{27}Input share parameters are assumed to be constant across all countries. Hence, the change in $f_{mi}$ is proportional to the change in $s_{mi}$.
inequality were an insignificant determinant of import demand schedules, one would not see significant changes in $f_{mi}$ (the same holds for $f_{ai}$ and $f_{ni}$). On the other hand, if one observed large changes in country-level import demand solely due to changes in the distribution of income, he could conclude that the model captures the link between income inequality and trade.

I conduct the following thought experiment to illustrate how income distribution shapes import demands at a given level of average income. I use the data on the distribution of real income in the USA and set $y_{id}$ in all other countries so that the distribution of income is exactly the same as in the USA. I keep the levels of average real income unchanged. In Figure 2, I plot changes in $f_{mi}$ versus the average real income per capita.

![Figure 2: Income Inequality and Import Demand](image)

Poor countries, where income inequality is relatively more pronounced, would spend a lower share of their total expenditure on manufacturing if they had less income inequality. This may seem counter-intuitive but at a given level of average real income, poor countries that exhibit relatively more income inequality must also have a higher import demand. The intuition behind is as follows. Positive demand for manufacturing goods can be realized only if at least one consumer in $i$ has an income higher than the subsistence level. In very poor countries, an equal distribution of income would imply that no consumer has enough income
to buy manufacturing goods. On the other hand, very high inequality could allow the richest households to have positive import demand. The results displayed in Figure 8 with regard to the impact of income inequality on trade is in line with the earlier empirical evidence (see Goldberg and Pavcnik, 2004; 2007) and the theoretical argument proposed by Linder (1961). This effect is completely missing in trade models with a representative consumer.

The model also has strong predictions with regard to the reverse effect, i.e., the effect of trade on income inequality. I discuss this link in the context of a counterfactual global trade policy liberalization scenario in Section 6.3.

To understand the mechanics behind the link between income inequality and trade, consider a hypothetical case of two countries with different income distributions and identical otherwise. For simplicity assume that \( d = \{1, 2, 3\} \). Total income, population and all prices in both countries are equal to unity. Incomes are distributed as \( \{0.3, 0.3, 0.4\} \) in country 1 and as \( \{0.1, 0.1, 0.8\} \) in country 2. Further assume that \( \mu p_{ai} = 0.2 \) in both countries. In that case total demands for manufacturing in countries 1 and 2, respectively, are:

\[
\begin{align*}
    f_{m1} \times Y_1 &= \frac{1}{3} \times (0.3 - 0.2) + \frac{1}{3} \times (0.3 - 0.2) + \frac{1}{3} \times (0.4 - 0.2) = 0.13 \\
    f_{m2} \times Y_2 &= \frac{1}{3} \times 0 + \frac{1}{3} \times 0 + \frac{1}{3} \times (0.8 - 0.2) = 0.2,
\end{align*}
\]

This is a simple example of how countries that are different with respect to their income distribution only can have very different import demand schedules.

In that sense, the model here is substantially different from other trade models with non-homothetic preferences. For example, Fieler (2011) provides a brief discussion of the role of income distribution in shaping international trade flows. She finds that income inequality has a very small impact, if any, on import demand schedules. The reason for this is twofold. First, she uses quintiles of the income distribution so that differences between the richest and

\footnote{In terms of the quantitative predictions of the model I calculate the squared distance between benchmark Gini-coefficients for each pair of countries and correlate it to the total trade. The correlation is \(-0.11\) which suggests that countries that are more similar in terms of the income distributions trade relatively more.}
the poorest consumers are not as pronounced as here. Second, Stone-Geary preferences have a discontinuity at the level of subsistence so that both the extensive and intensive margins of consumption are important. Preferences specified in Fieler (2011) are continuous in a sense that each consumer always spends some part of her income on each type of good.\footnote{This is a well-known property of any CES-related demand system.}

6 Counterfactual experiment

For the counterfactual experiment, it is useful to express the model in relative changes. Let $a$ denote benchmark and $a'$ counterfactual values of some variable, then the relative change is $\hat{a} = a'/a$. This approach is particularly convenient because one may assume that the primitives of the model, $\tau_{in}$ and $\lambda_i$, do not respond to indirect shocks and one can conduct counterfactual experiments without having estimated these unobservable fundamentals.\footnote{See Dekle, Eaton and Kortum (2007), Caliendo and Parro (2011), Egger and Nigai (2011)}

In the counterfactual experiment, I globally eliminate all import tariffs to assess the effect of this hypothetical policy on real income, welfare and income distribution. Tariffs are asymmetric in the outset, hence for this counterfactual exercise I reduce tariffs in an asymmetric manner:

$$t'_{a,\text{in}} = 1 \quad \text{and} \quad t'_{m,\text{in}} = 1 \quad \text{such that} \quad \hat{t}_{a,\text{in}} = (t_{a,\text{in}})^{-1}, \hat{t}_{m,\text{in}} = (t_{m,\text{in}})^{-1} \quad \text{for all} \quad i, n. \quad (6.1)$$

which effectively means zero MFN-tariffs for all countries in both tradable sectors. I list expressions for the counterfactual values of all variables and describe the solution algorithm and the data in the Appendix.

For the comparative static experiment I choose three outcomes of interest: average real income $\bar{y}_i$,\footnote{Real income may be measured in many different ways, here I stick to the conventional definition, i.e., real income is a ratio of nominal income to a country-specific price index.} welfare (decile-specific $\omega_{id}$ and aggregate $W_i$), and the within-country income
distribution.

6.1 Trade liberalization, real income and welfare

Conventional wisdom suggests that trade liberalization on average has positive aggregate effects in terms of real income. First, let me consider the effect of a complete elimination of tariffs on the average real income per capita as parameterized for the year 1996. I plot the counterfactual change in $\bar{y}_i$ against its initial values in Figure 3.

The results in Figure 3 are consistent with the large body of literature on the effects of trade liberalization. Numerous empirical and theoretical works found that trade liberalization leads to higher income per capita on average, much more so for small economies. Smaller countries gain relatively more because with lower barriers they are able to specialize on the production of goods where productivity is high. In this experiment, bigger countries lose a little in terms of the average real income per capita. The reason for this is twofold. First, the initial tariff matrices are asymmetric and developing countries initially face relatively higher
tariffs. Accordingly, they benefit relatively more from trade liberalization. Second, in the counterfactual equilibrium rich countries face tougher competition from poor countries that start exporting relatively more through specialization. In general, the results of the counterfactual exercise, as far as changes in the average real income per capita are concerned, are very much in line with both the empirical literature and other computable general equilibrium models of trade (for example, see Alvarez and Lucas, 2007). The exact counterfactual results for all countries and all relevant variables are in Tables 3-4 in the Appendix.

Next, let me examine whether average real income per capita is an adequate metric for the evaluation of welfare effects of trade liberalization for different type of consumers. For each decile $d$ in each country $i$, I calculate counterfactual change, $\hat{\omega}_{id} = \frac{\omega'_{id}}{\omega_{id}}$.

In Figure 4, I plot welfare changes of the 1st, 5th and 10th deciles of the distribution of consumers in each country against the change in the average real income per capita. The results of the counterfactual exercise for all deciles are in Tables 3-4.

Figure 4: Change in Average Real Income per Capita versus Change in Welfare (by decile)

If average real income per capita were an adequate measure of welfare for all types of consumers the scatter points would lie on the 45 degree line in all three panels. Serious deviations from the 45 degree line suggest that $\bar{y}_i$ is not an appropriate metric for some consumer groups. Figure 4 shows that as one goes from the richest to the poorest households, average

---

32 As a sensitivity check, I conduct a counterfactual exercise which reduces trade costs symmetrically by the same margin. In that case, all countries gain but smaller countries still gain relatively more. The results are available upon request.
real income per capita becomes less and less relevant. Notice that changes in welfare and average real income per capita are practically identical for the decile of consumers with the highest income per capita. The relationship is much weaker for consumers in the 5th decile of the distribution (although still positive). Finally, the left panel of the figure suggests that changes in the average income per capita and changes in welfare for the poorest income groups are largely unrelated.

To formally show that average income per capita is not a good predictor of welfare gains (at least for some consumer groups) I run the following regression:

\[ \hat{\omega}_{id} = \pi_d \hat{y}_i + \text{error}_{id}. \]  

(6.2)

If \( \hat{y}_i \) were a good measure of welfare gains then \( \pi_d \) would be close to unity. The results in Table 2 suggest that this is true only for the highest and second highest deciles. For all other deciles the estimate of \( \pi_d \) is considerably different from unity, with high standard errors and low explanatory power.

<table>
<thead>
<tr>
<th>d = 10</th>
<th>( \hat{\pi}_d )</th>
<th>std.error</th>
<th>( R^2 )</th>
<th>Max</th>
<th>Min</th>
<th>Mean</th>
<th>Std. dev.</th>
<th>( s^+_d )</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.26</td>
<td>0.47</td>
<td>0.01</td>
<td>88.15</td>
<td>-11.33</td>
<td>2.34</td>
<td>12.73</td>
<td>0.49</td>
<td></td>
</tr>
<tr>
<td>d = 9</td>
<td>0.27</td>
<td>0.14</td>
<td>16.83</td>
<td>-8.48</td>
<td>1.05</td>
<td>4.6</td>
<td>0.58</td>
<td></td>
</tr>
<tr>
<td>d = 8</td>
<td>0.4</td>
<td>0.11</td>
<td>11.21</td>
<td>-7.13</td>
<td>0.85</td>
<td>3.59</td>
<td>0.61</td>
<td></td>
</tr>
<tr>
<td>d = 7</td>
<td>0.49</td>
<td>0.09</td>
<td>9.32</td>
<td>-6.24</td>
<td>0.71</td>
<td>2.97</td>
<td>0.64</td>
<td></td>
</tr>
<tr>
<td>d = 6</td>
<td>0.57</td>
<td>0.08</td>
<td>8.64</td>
<td>-5.59</td>
<td>0.61</td>
<td>2.52</td>
<td>0.66</td>
<td></td>
</tr>
<tr>
<td>d = 5</td>
<td>0.64</td>
<td>0.07</td>
<td>8.08</td>
<td>-4.95</td>
<td>0.49</td>
<td>2.12</td>
<td>0.67</td>
<td></td>
</tr>
<tr>
<td>d = 4</td>
<td>0.72</td>
<td>0.06</td>
<td>6.22</td>
<td>-4.34</td>
<td>0.36</td>
<td>1.73</td>
<td>0.67</td>
<td></td>
</tr>
<tr>
<td>d = 3</td>
<td>0.79</td>
<td>0.05</td>
<td>4.35</td>
<td>-3.68</td>
<td>0.24</td>
<td>1.34</td>
<td>0.65</td>
<td></td>
</tr>
<tr>
<td>d = 2</td>
<td>0.87</td>
<td>0.04</td>
<td>2.68</td>
<td>-2.87</td>
<td>0.1</td>
<td>0.97</td>
<td>0.57</td>
<td></td>
</tr>
<tr>
<td>d = 1</td>
<td>1.02</td>
<td>0.03</td>
<td>1.01</td>
<td>-2.88</td>
<td>-0.14</td>
<td>0.59</td>
<td>0.42</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Standard errors are robust to an unknown form of heteroskedasticity. The number of observations for each regression is 92.

For each decile \( d \) in each country \( i \), I also calculate the measurement error \( me_{id} \). Recall, that I defined it as:
Expression in (6.3) measures by how much changes in the average real income per capita overpredict changes in decile-specific welfare. I plot $me_{id}$ in Figure 5.

The dispersion of $me_{d}$ is considerably higher for relatively poor consumers. For the poorest decile the measurement errors are in the interval $[-11\%, 88\%]$ with relatively equal shares of positive (overprediction) errors and negative (underprediction) errors. I report the share of positive measurement errors, denoted by $s^+_d$, along with the other descriptive statistics in Table 2

The range of $me_{d}$ becomes smaller as one goes from the poorest to the richest consumer. The range is between $[-5\%, 8\%]$ for the median consumer and between $[-3\%, 1\%]$ for the richest consumer, respectively. The same tendency holds for the dispersion of errors measured in terms of the standard deviation. The statistics in Table 2 suggest that overall $me_{d}$ is small for $d = 1$, hence $\hat{y}_i$ is a good measure of welfare for very rich consumers.

There is an inverse U-shaped relationship between $s^+_d$ and $d$. Average real income per capita tends to overestimate the gains from trade for consumers in the middle of the income
distribution. However, this measure underestimates the gains for consumers in the right tail of the income distribution. The reason for this are differences in the relative price and nominal income effects that vary across different deciles.

Policy makers may be interested in targeting certain consumer groups when considering trade liberalization policy. However, it may also be useful to have a measure of aggregate welfare gains of a country. As is well known, this is not an easy task. Welfare effects are largely heterogeneous across different consumer groups which makes evaluating overall welfare gains quite challenging. One way to proceed is to assume a simple, yet intuitive, unweighted utilitarian social welfare function\textsuperscript{33} such that the social welfare is the sum of utility measures across different deciles of consumers: \( W_i = \sum_d \omega_{i,d} \). Is \( \bar{y}_i \) a good measure of the overall social welfare gains? In Figure \ref{fig6}, I plot counterfactual changes in the average real income per capita versus changes in the measure of aggregate welfare \( W_i \).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure6.png}
\caption{Change in Average Real Income per Capita versus Change in Total Welfare}
\end{figure}

Figure \ref{fig6} suggests that average real income per capita is a noisy measure of the aggregate welfare. The range of the measurement error is between \(-6\%\) and \(8\%\). On average, changes in real income per capita tend to be larger than changes in aggregate welfare. The share

\textsuperscript{33}The results are even stronger for some other measures of social welfare such as Rawlsian welfare function.
of positive errors is $s^+ = 0.58$ which suggests that $\bar{y}_t$ is likely to overpredict true aggregate welfare gains.

### 6.2 On the mechanics of heterogeneous welfare effects

Welfare gains of poor consumers largely differ from the predictions based on the change in average real income per capita. For example, according to Figure 3 consumers in Mexico and Chile on average should gain approximately 2.5% and 1% in welfare, respectively. The effects are reversed for the poorest consumers in both countries. Welfare of poor consumers in Mexico and Chile actually falls by about 20% and 5% respectively. This is depicted in Figure 7 where I plot welfare gains of the poorest consumer groups (lowest decile of per-capita income) in all countries.

![Figure 7: Trade Liberalization and Welfare (for the 10th Decile)](image)

What exactly drives these differences? To understand the mechanics behind, I conduct an additional experiment. Up to this point, I assumed that trade liberalization takes place instantaneously. However, in order to understand the main drivers of the results, it is useful to consider liberalization as a gradual process. Let $\varsigma$ be a step function such that $\varsigma = (0, \ldots, 20)$, each step is a discrete jump from the benchmark towards full trade liberalization. Hence, at $\varsigma = 0$ the model is exactly as in the benchmark case, and at $\varsigma = 20$ the model is
exactly as in the case of full trade liberalization. Let $t_{a,in}^{\varsigma}$ and $t_{m,in}^{\varsigma}$ be the counterfactual values of tariffs at step $\varsigma$ in the agricultural and manufacturing sectors, respectively. I define them as follows:

$$t_{a,in}^{\varsigma} = t_{a,in} - \frac{\varsigma}{20}(t_{a,in} - 1) \quad \text{and} \quad t_{m,in}^{\varsigma} = t_{m,in} - \frac{\varsigma}{20}(t_{m,in} - 1) \quad \text{for all} \ i, n. \quad (6.4)$$

For each step $\varsigma$, I calculate the counterfactual change (in percent) in $Y_{id}$, $P_{id}$, and $\omega_{id}$. Notice that one can decompose welfare gains $\Delta \omega_{id}$ (hereafter $\Delta$ denotes change in %) into the nominal income effect, $\Delta Y_{id}$, and the price effect $- \Delta P_{id}$ as:

$$\Delta \omega_{id} = \Delta Y_{id} - \Delta P_{id} \quad (6.5)$$

In Table 2, I argued that changes in average income per capita do not reflect individual welfare gains of poor consumers. In fact, if one employs $\omega_{id}$ instead of $\bar{y}_i$ as a measure of welfare the effects are reversed for many countries in the sample. For example, counterfactual change in $\bar{y}_i$ in Chile is positive (around 1 % in Figure 3). On the other hand, Figure 7 suggests that the poorest decile in Chile loses in terms of welfare (around 5%). What drives this large difference? I use the decomposition in (6.5) to answer this question. The model predicts that real returns to labor and capital increase by 3% in Chile. At the same time, zero-MFN tariffs imply that consumers lose all of the tariff revenues. This trade-off is good for those who own a lot of capital and bad for those who own little.

Higher labor and capital costs increase prices of agricultural goods by relatively more. Poor consumers spend most of their income on agricultural goods. Hence, the price effect has an additional negative effect on their welfare. In Figure 8 I plot total welfare gains, income and price effects for the 1st, 5th and 10th deciles in Chile for each counterfactual step $\varsigma$. Notice

---

34 Log-linearize (2.1) and multiply both sides by 100 to get (6.5).
35 That the home bias is larger in the agricultural sector than in manufacturing is a well-documented fact.
that as countries start reducing tariff revenues, consumers in the poorest decile lose in terms of the nominal income and prices. This happens because they own very little capital so that the increase in the price of that factor cannot compensate for losses in tariff revenues. Hence, their total welfare gains are strictly negative. Consumers in the median decile own enough capital to have positive total nominal income effects. But their decile-specific price index increases relatively more. As a result, their total welfare gains are negative. Finally, the richest households in Chile own enough capital so that their income effect overcompensates the increase in the price index. This leads to positive welfare gains. It bears noting that the price effects are strongest for the poorest consumer group.

6.3 Trade liberalization and income distribution

The purpose of this section is to demonstrate that the model delivers quantitative predictions consistent with the empirical literature in terms of the effect of trade liberalization on income inequality. The empirical evidence suggests that, during the last quarter of the twentieth century, many developing countries experienced acute increase in the income inequality part
of which can be attributed to higher trade (see Goldberg and Pavcnik, 2004; 2007). Does the model provide credible predictions in that respect?

To answer this question I have to measure real income per capita of different consumer groups in a way consistent with the empirical literature. For that, I use decile-specific income $y_{id}$ measured as a ratio of total nominal income of consumers of type $d$ in country $i$ deflated by the country-specific price index:

$$y_{id} = \frac{Y_{id}}{L_{id}P_{ai}^{\sigma_{ai}} P_{mi}^{\sigma_{mi}} P_{ni}^{\sigma_{ni}}}.$$ (6.6)

I use the benchmark and counterfactual values of $y_{id}$ to calculate the Gini-coefficient, denoted by $G_i$ in the pre and post-liberalization periods. I plot the results of the counterfactual experiment in Figure 9.

Figure 9: The Effect of Trade Liberalization on the Distribution of Income

Global liberalization of trade increases inequality for most countries. The majority of develop-

36 A notable exception from numerous case studies conducted on the subject is Porto (2006) who estimates distributional effects of joining MERCOSUR for Argentina. The author uses household survey data and shows that on average joining MERCOSUR had positive effects on welfare of poor and middle-income consumers and reduced inequality. My results do not contradict Porto’s findings. To simulate the natural experiment examined in Porto (2006), I conduct a separate counterfactual exercise. I reduce import tariffs set by Argentina only. The model predicts that inequality in Argentina decreases by 2.2%.

37 I repeated the exercise using alternative measures of inequality such as the percentile ratio. The results turn out to be quantitatively robust to those manipulations.
opining countries experiences an increase in income inequality. The effects in the rich countries are less pronounced.

Essentially, the effects of trade liberalization on the distribution of real income can be decomposed into changes in nominal income and changes in common price index as illustrated in Section 6.2. It is intuitive that a reduction in income inequality must come from either higher income of consumers in the left tail of the distribution or equivalently lower income of consumers in the right tail of the distribution. As I argued, trade liberalization is likely to raise income of the rich and reduce income of the poor which leads to the increase in income inequality as in Figure 9.

7 Conclusion

I have developed a multi-country model of trade with non-homothetic preferences and heterogeneous consumers. The model reflects empirically established facts in a few novel dimensions. For instance, the model features a strong link between income inequality within countries and trade which has been missing in quantitative models of trade.

Perhaps, one of the most important features of the model is its ability to predict large heterogeneity of consumption patterns of different consumer groups within a country. I argue that this heterogeneity must be taken into account when evaluating welfare gains from trade. I show that conventional measures thereof do not capture true welfare gains for poor and middle-income consumers and tend to introduce a measurement error in the magnitude between -6% and 8% of aggregate welfare gains.

Admittedly, one of the caveats of the model is the assumption of an exogenous and stationary capital distribution. However, in a multi-country framework endogenous accumulation and/or the non-stationary distribution of capital would complicate the model significantly. I leave this for future research.
References


POOLE, W. Free trade: why are economists and noneconomists so far apart? *Presentation to the Globalization and Outsourcing Conference* (June 2004).


Appendix

7.1 Data

The reference year for all the 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 $D_i$, $D_{ai}$ and $D_{mi}$ are calculated as total imports minus total exports in the respective sector. Data on total GDP, average real GDP per capita, and current account balance are from the World Bank’s World Development Indicators (WDI) database. The data on the aggregate expenditure shares $s_{ai}$, $s_{mi}$ and $s_{ni}$, and on $p_{ai}$ are from the Penn World Tables. The input-output tables are from the OECD’s Structural Analysis (STAN) database. Distance and adjacency data are from the Centre d’Études Prospectives et d’Informations Internationales (CEPII). Bilateral tariff data are from the Market Access Map Database (MacMap) which provides tariff data at the 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 tariff data provided by Mayer, Paillacar and Zignago (2008). Data on the distribution of income are from UN-WIDER World Income Inequality Database (WIID). If missing, the data were taken from Klaus and Squire (1996), and/or Milanovic and Yitzhaki (2001).

7.2 Results of the counterfactual experiment

I report all results of the counterfactual experiment in Tables 3-4.

---

38Expenditure 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 where $p_{ai}$ is a dependant and $\bar{y}_i$ explanatory variable.
Table 3: Results of the Counterfactual Experiment

<table>
<thead>
<tr>
<th>ISO</th>
<th>% change relative to the benchmark</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARG</td>
<td>-41.7</td>
</tr>
<tr>
<td>BAH</td>
<td>3.5</td>
</tr>
<tr>
<td>BMZ</td>
<td>7.0</td>
</tr>
<tr>
<td>CAN</td>
<td>-41.7</td>
</tr>
<tr>
<td>CAF</td>
<td>3.5</td>
</tr>
<tr>
<td>CHL</td>
<td>-41.7</td>
</tr>
<tr>
<td>CHN</td>
<td>3.5</td>
</tr>
<tr>
<td>CIV</td>
<td>-41.7</td>
</tr>
<tr>
<td>COL</td>
<td>3.5</td>
</tr>
<tr>
<td>CYP</td>
<td>-41.7</td>
</tr>
<tr>
<td>DEU</td>
<td>3.5</td>
</tr>
<tr>
<td>DNK</td>
<td>-41.7</td>
</tr>
<tr>
<td>ETH</td>
<td>3.5</td>
</tr>
<tr>
<td>FIN</td>
<td>-41.7</td>
</tr>
<tr>
<td>FJI</td>
<td>3.5</td>
</tr>
<tr>
<td>FRA</td>
<td>-41.7</td>
</tr>
<tr>
<td>GBR</td>
<td>3.5</td>
</tr>
<tr>
<td>GHA</td>
<td>3.5</td>
</tr>
<tr>
<td>GMB</td>
<td>3.5</td>
</tr>
<tr>
<td>GRC</td>
<td>3.5</td>
</tr>
<tr>
<td>GTM</td>
<td>3.5</td>
</tr>
<tr>
<td>GUI</td>
<td>3.5</td>
</tr>
<tr>
<td>HND</td>
<td>3.5</td>
</tr>
<tr>
<td>HRV</td>
<td>3.5</td>
</tr>
<tr>
<td>HUN</td>
<td>3.5</td>
</tr>
<tr>
<td>IDN</td>
<td>3.5</td>
</tr>
<tr>
<td>IND</td>
<td>3.5</td>
</tr>
<tr>
<td>ISR</td>
<td>3.5</td>
</tr>
<tr>
<td>ITA</td>
<td>3.5</td>
</tr>
<tr>
<td>JPN</td>
<td>3.5</td>
</tr>
<tr>
<td>KOR</td>
<td>3.5</td>
</tr>
<tr>
<td>LVA</td>
<td>3.5</td>
</tr>
<tr>
<td>LBN</td>
<td>3.5</td>
</tr>
<tr>
<td>LBY</td>
<td>3.5</td>
</tr>
<tr>
<td>MAR</td>
<td>3.5</td>
</tr>
<tr>
<td>MEX</td>
<td>3.5</td>
</tr>
<tr>
<td>MGL</td>
<td>3.5</td>
</tr>
<tr>
<td>MNL</td>
<td>3.5</td>
</tr>
<tr>
<td>MYS</td>
<td>3.5</td>
</tr>
<tr>
<td>NGR</td>
<td>3.5</td>
</tr>
<tr>
<td>NLD</td>
<td>3.5</td>
</tr>
<tr>
<td>NOR</td>
<td>3.5</td>
</tr>
<tr>
<td>NZL</td>
<td>3.5</td>
</tr>
<tr>
<td>PAK</td>
<td>3.5</td>
</tr>
<tr>
<td>PHL</td>
<td>3.5</td>
</tr>
<tr>
<td>PLK</td>
<td>3.5</td>
</tr>
<tr>
<td>POL</td>
<td>3.5</td>
</tr>
<tr>
<td>PRK</td>
<td>3.5</td>
</tr>
<tr>
<td>QAT</td>
<td>3.5</td>
</tr>
<tr>
<td>QUN</td>
<td>3.5</td>
</tr>
<tr>
<td>ROU</td>
<td>3.5</td>
</tr>
<tr>
<td>RSA</td>
<td>3.5</td>
</tr>
<tr>
<td>SDN</td>
<td>3.5</td>
</tr>
<tr>
<td>SGP</td>
<td>3.5</td>
</tr>
<tr>
<td>SWE</td>
<td>3.5</td>
</tr>
<tr>
<td>TUN</td>
<td>3.5</td>
</tr>
<tr>
<td>TUR</td>
<td>3.5</td>
</tr>
<tr>
<td>TZA</td>
<td>3.5</td>
</tr>
<tr>
<td>UGA</td>
<td>3.5</td>
</tr>
<tr>
<td>UVG</td>
<td>3.5</td>
</tr>
<tr>
<td>WES</td>
<td>3.5</td>
</tr>
<tr>
<td>YEM</td>
<td>3.5</td>
</tr>
<tr>
<td>ZAF</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Note: The table shows the % change relative to the benchmark for various countries.
<table>
<thead>
<tr>
<th>ISO</th>
<th>$y_{12}$</th>
<th>$y_{13}$</th>
<th>$y_{14}$</th>
<th>$y_{15}$</th>
<th>$y_{16}$</th>
<th>$y_{17}$</th>
<th>$y_{18}$</th>
<th>$y_{19}$</th>
<th>$y_{20}$</th>
<th>$y_{21}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITA</td>
<td>4.09</td>
<td>3.25</td>
<td>2.35</td>
<td>1.45</td>
<td>0.55</td>
<td>0.63</td>
<td>0.71</td>
<td>0.79</td>
<td>0.87</td>
<td>0.97</td>
</tr>
<tr>
<td>JAM</td>
<td>4.09</td>
<td>3.25</td>
<td>2.35</td>
<td>1.45</td>
<td>0.55</td>
<td>0.63</td>
<td>0.71</td>
<td>0.79</td>
<td>0.87</td>
<td>0.97</td>
</tr>
<tr>
<td>JPN</td>
<td>3.25</td>
<td>2.35</td>
<td>1.45</td>
<td>0.55</td>
<td>0.63</td>
<td>0.71</td>
<td>0.79</td>
<td>0.87</td>
<td>0.97</td>
<td>0.92</td>
</tr>
<tr>
<td>KEN</td>
<td>2.35</td>
<td>1.45</td>
<td>0.55</td>
<td>0.63</td>
<td>0.71</td>
<td>0.79</td>
<td>0.87</td>
<td>0.97</td>
<td>0.92</td>
<td>0.89</td>
</tr>
<tr>
<td>KOR</td>
<td>1.45</td>
<td>0.55</td>
<td>0.63</td>
<td>0.71</td>
<td>0.79</td>
<td>0.87</td>
<td>0.97</td>
<td>0.92</td>
<td>0.89</td>
<td>0.86</td>
</tr>
<tr>
<td>LKA</td>
<td>0.55</td>
<td>0.63</td>
<td>0.71</td>
<td>0.79</td>
<td>0.87</td>
<td>0.97</td>
<td>0.92</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
</tr>
<tr>
<td>MAR</td>
<td>0.63</td>
<td>0.71</td>
<td>0.79</td>
<td>0.87</td>
<td>0.97</td>
<td>0.92</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
</tr>
<tr>
<td>MDG</td>
<td>0.71</td>
<td>0.79</td>
<td>0.87</td>
<td>0.97</td>
<td>0.92</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
</tr>
<tr>
<td>MEX</td>
<td>0.79</td>
<td>0.87</td>
<td>0.97</td>
<td>0.92</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
</tr>
<tr>
<td>MLI</td>
<td>0.87</td>
<td>0.92</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
</tr>
<tr>
<td>MOZ</td>
<td>0.92</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
<td>0.71</td>
</tr>
<tr>
<td>MWI</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
<td>0.71</td>
<td>0.70</td>
</tr>
<tr>
<td>NGA</td>
<td>0.97</td>
<td>0.92</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
</tr>
<tr>
<td>NLD</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
<td>0.71</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
</tr>
<tr>
<td>NOR</td>
<td>0.94</td>
<td>0.93</td>
<td>0.93</td>
<td>0.93</td>
<td>0.93</td>
<td>0.93</td>
<td>0.93</td>
<td>0.93</td>
<td>0.93</td>
<td>0.93</td>
</tr>
<tr>
<td>PHL</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
<td>0.71</td>
<td>0.70</td>
</tr>
<tr>
<td>PNG</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
<td>0.71</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
</tr>
<tr>
<td>PR</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
<td>0.71</td>
<td>0.70</td>
</tr>
<tr>
<td>RWA</td>
<td>0.92</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
<td>0.71</td>
</tr>
<tr>
<td>SEN</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
<td>0.71</td>
<td>0.70</td>
</tr>
<tr>
<td>SLE</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
<td>0.71</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
</tr>
<tr>
<td>SLV</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
<td>0.71</td>
<td>0.70</td>
</tr>
<tr>
<td>SWZ</td>
<td>0.92</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
<td>0.71</td>
</tr>
<tr>
<td>TCD</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
<td>0.71</td>
<td>0.70</td>
</tr>
<tr>
<td>TGO</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
<td>0.71</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
</tr>
<tr>
<td>THA</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
<td>0.71</td>
<td>0.70</td>
</tr>
<tr>
<td>TUN</td>
<td>0.92</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
<td>0.71</td>
</tr>
<tr>
<td>TZA</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
<td>0.71</td>
<td>0.70</td>
</tr>
<tr>
<td>UGA</td>
<td>0.92</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
<td>0.71</td>
</tr>
<tr>
<td>VEN</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
<td>0.71</td>
<td>0.70</td>
</tr>
<tr>
<td>ZAF</td>
<td>0.92</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
<td>0.71</td>
</tr>
<tr>
<td>ZMB</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
<td>0.71</td>
<td>0.70</td>
</tr>
<tr>
<td>ZWE</td>
<td>0.92</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
<td>0.71</td>
</tr>
</tbody>
</table>

Table 4: RESULTS OF THE EXPERIMENTAL FACTOR (continued)
7.3 Model solution: counterfactual experiment

Dekle, Eaton and Kortum (2007) proposed a way to solve for counterfactual values in Ricardoian 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.

In my counterfactual experiment I uniformly set all tariffs to unity. Given this exogenous change and the data on real income and trade, I can solve for all other counterfactual values as in Table 5.

<table>
<thead>
<tr>
<th>variable</th>
<th>Benchmark</th>
<th>Counterfactual</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p_{ai}$</td>
<td>$p_{ai} = \left( \sum_{i}^{N} \left( \kappa_{ai} \lambda_{a,i} \ell_{m,i} \right) - \theta_{a} \right)^{- \frac{1}{\theta_{a}}} $</td>
<td>$p'<em>{ai} = p</em>{ai} \left( \sum_{i}^{N} x_{a,i} \left( \kappa_{ai} \lambda_{a,i} \ell_{m,i} \right) - \theta_{a} \right)^{- \frac{1}{\theta_{a}}} $</td>
</tr>
<tr>
<td>$p_{mi}$</td>
<td>$p_{mi} = \left( \sum_{i}^{N} \left( \kappa_{mi} \lambda_{m,i} \ell_{m,i} \right) - \theta_{m} \right)^{- \frac{1}{\theta_{m}}} $</td>
<td>$p'<em>{mi} = p</em>{mi} \left( \sum_{i}^{N} x_{m,i} \left( \kappa_{mi} \lambda_{m,i} \ell_{m,i} \right) - \theta_{m} \right)^{- \frac{1}{\theta_{m}}} $</td>
</tr>
<tr>
<td>$p_{ni}$</td>
<td>$p_{ni} = \gamma_{n} (1 - \nu)<em>{i} \phi \left( P</em>{ni}^{\phi} \right)^{1 - \phi}$</td>
<td>$p'<em>{ni} = p</em>{ni} \left( \gamma_{n} (1 - \nu)<em>{i} \phi \left( P</em>{ni}^{\phi} \right)^{1 - \phi} \right)$</td>
</tr>
<tr>
<td>$x_{m,in}$</td>
<td>$x_{m,in} = \sum_{i}^{N} \left( \kappa_{mn} \lambda_{m,in} \ell_{m,in} \right) - \theta_{m}$</td>
<td>$x'<em>{m,in} = \sum</em>{i}^{N} x_{m,in} \left( \kappa_{mn} \lambda_{m,in} \ell_{m,in} \right) - \theta_{m}$</td>
</tr>
<tr>
<td>$x_{a,in}$</td>
<td>$x_{a,in} = \sum_{i}^{N} \left( \kappa_{an} \lambda_{a,in} \ell_{a,in} \right) - \theta_{a}$</td>
<td>$x'<em>{a,in} = \sum</em>{i}^{N} x_{a,in} \left( \kappa_{an} \lambda_{a,in} \ell_{a,in} \right) - \theta_{a}$</td>
</tr>
<tr>
<td>$y_{id}$</td>
<td>$y_{id} = \frac{w_{i} \left( 1 - \frac{\nu}{\nu_{id}} + 1 \right) + v_{i}}{P_{ai} P_{mi} P_{ni}}$</td>
<td>$y'<em>{id} = \frac{\hat{w}</em>{i} y_{id} + v'<em>{i}}{P</em>{ai} P_{mi} P_{ni}}$</td>
</tr>
<tr>
<td>$v_{i}$</td>
<td>$v_{i} = c_{i} + \bar{y}<em>{i} \sum</em>{n} \left( f_{mi} x_{i,in} \ell_{i,in} + f_{ai} x_{a,in} \ell_{a,in} \right)$</td>
<td>$v'<em>{i} = c</em>{i} + \bar{y}<em>{i} \sum</em>{n} \left( f'<em>{mi} x'</em>{i,in} \ell'<em>{i,in} + f</em>{ai} x'<em>{a,in} \ell'</em>{a,in} \right)$</td>
</tr>
<tr>
<td>$\omega_{i,d}$</td>
<td>$\omega_{i,d} = y_{id} \frac{P_{ai} P_{mi} P_{ni}}{\bar{x}<em>{a,in} \bar{x}</em>{a,im} \bar{x}<em>{a,im} \bar{x}</em>{a,im}}$</td>
<td>$\omega'<em>{i,d} = y'</em>{id} \frac{P_{ai} P_{mi} P_{ni}}{\bar{x}<em>{a,in} \bar{x}</em>{a,im} \bar{x}<em>{a,im} \bar{x}</em>{a,im}}$</td>
</tr>
</tbody>
</table>

Notes: Total per-capita transfers denoted as $v_{i}$ are calculated as a sum of tariff revenues and exogenous cross-country transfers, $c_{i}$ (net of trade imbalances).

To solve for the counterfactual change in wages $\hat{w}_{i}$ I use a market clearing condition as in (3.18):
\[
(\hat{w}_iY_i + V'_i) \sum_{n=1}^{N} (f'_{m,n}x'_{t,in} + f'_{a,n}x'_{a,in}) - D_i = \sum_{n=1}^{N} (\hat{w}_nY_n + V'_n) (f'_{m,n}x'_{m,ni} + f'_{a,n}x'_{a,ni})
\] (7.1)

In practice, the solution algorithm boils down to finding a fixed point for a series of contraction mappings. For further discussion refer to Alvarez and Lucas (2007) and Dekle, Eaton and Kortum (2007).

### 7.4 Derivation details (NOT FOR PUBLICATION)

#### Derivation of demand shares in (3.2)-(3.4)

Use the utility function and the budget constraint in (3.1) to formulate the lagrangian as follows:

\[
L_{id} = (c_{ni}^{\beta}c_{mi}^{1-\beta})^{\alpha}(c_{ai} - \mu)^{1-\alpha} - \vartheta \left( y_{id} - c_{ni}p_{ni} + c_{mi}p_{mi} + c_{ai}p_{ai} \right),
\] (7.2)

the first-order conditions are as follows:

\[
\frac{\partial L_{id}}{\partial c_{ni}} : \alpha \beta c_{ni}^{\alpha \beta - 1}c_{mi}^{(1-\beta)\alpha}(c_{ai} - \mu)^{1-\alpha} = \vartheta p_{ni}
\] (7.3)

\[
\frac{\partial L_{id}}{\partial c_{mi}} : (1 - \beta)\alpha c_{ni}^{\alpha \beta}c_{mi}^{(1-\beta)\alpha - 1}(c_{ai} - \mu)^{1-\alpha} = \vartheta p_{mi}
\] (7.4)

\[
\frac{\partial L_{id}}{\partial c_{ai}} : (1 - \alpha)(c_{ni}^{\beta}c_{mi}^{1-\beta})^{\alpha}(c_{ai} - \mu)^{-\alpha} = \vartheta p_{ai}
\] (7.5)

Take the ratio of (7.3) to (7.4) to establish the following relationship:

\[
\frac{\beta}{1 - \beta} \frac{c_{mi}}{c_{ni}} = \frac{p_{ni}}{p_{mi}}
\] (7.6)

and divide (7.3) by (7.5) to establish the following:

\[
\frac{\alpha \beta}{1 - \alpha} \frac{c_{ai} - \mu}{p_{ai}} = \frac{p_{ni}}{p_{ai}}
\] (7.7)
Recall that the budget constraint reads:

\[ y_{id} = c_{ni}p_{ni} + c_{mi}p_{mi} + c_{ai}p_{ai}, \]  

(7.8)

plug \( p_{mi}c_{mi} \) from (7.6) and \( p_{ai}c_{ai} \) from (7.7) into the budget constraint to get:

\[ \frac{1 - \beta}{\beta} p_{ni}c_{ni} + p_{ni}c_{ni} + \frac{1 - \alpha}{\alpha \beta} p_{ni}c_{ni} = y_{id} \]  

(7.9)

Equation (7.9) can be simplified as follows:

\[ \frac{1}{\alpha \beta} p_{ni}c_{ni} + \mu p_{ai} = y_{id}, \]

\[ \Rightarrow p_{ni}c_{ni} = \alpha \beta (y_{id} - \mu p_{ai}). \]  

(7.10)

I restrict the range of \( p_{ni}c_{ni} \) to \([0; +\infty)\), hence \( p_{ni}c_{ni} \) is positive whenever \( y_{id} > \mu p_{ai} \) and zero otherwise. The two remaining demand systems in (3.2)-(3.4) immediately follow.

**Derivation of prices in (3.11) and (3.14)**

Recall the production function of a variety \( q \) in \( i \):

\[ m_i(q) = z_{im}(q)(l_i^\nu k_i^{1-\nu})^{\xi}(n_i^\zeta m_i^{1-\zeta})^{1-\xi}, \]  

(7.11)

let \( vc_i = (w_i^\nu r_i^{1-\nu})^{\xi}(p_{ni}^\zeta p_{mi}^{1-\zeta})^{1-\xi} \). Then, we can rewrite the price of the variety \( q \) as:

\[ p(q)_{mi} = z_{im}(q)v_i, \]  

(7.12)

In the open economy equilibrium, each country shops around for the lowest price of each variety \( q \). In other words,

\[ p(q)_{mi} = \min_{\ell} \{ z_{im}(q)vc_{\ell}r_{\ell i}t_{\ell i} \}; \]  

(7.13)
Since $z_{im}(q)$ is distributed Frechet, $z_{im}(q)^{-\theta_m}$ is distributed exponential with mean $\lambda_i$. A well known property of the exponential distribution is:

$$p^\theta(q)_{mi} \sim \exp \left( \sum_{\ell=1}^{\ell=N} \lambda_\ell (vc_\ell t_{i\ell})^{-\theta} \right)$$  \hfill (7.14)

Denote $\tilde{p} = p^\theta(q)_{mi}$ and use change-of-variables formula to derive the $p_{mi}$ from the CES specification:

$$p_{mi}^{1-\sigma_m} = \tau_{i\ell t_{i\ell}} \int_0^1 \tilde{p}^{1-\sigma_m} vc_\ell \exp(-vc_\ell \tilde{p}) d\tilde{p},$$

$$\Rightarrow p_{mi} = \sum (\Gamma_m (\lambda_{mi} (w_i^{-1})^{1-\nu} (-p_{mi}^{-1} \xi (p_{mi}^{-1})^{1-\xi} t_{i\ell t_{i\ell}})^{-\theta_m})^{-\frac{1}{\theta_m}},$$

$$\Rightarrow p_{mi} = \left( \sum_{\ell} (\kappa_{\ell \tau_{m,i\ell} t_{m,i\ell}})^{-\theta_m} \right)^{-\frac{1}{\theta_m}}. \hfill (7.15)$$

The same applies to the agricultural aggregate.

**Derivation of trade shares in (3.15)**

There is a mass of different varieties $q$. Hence, the trade share $x_{m,in}$ equals the probability that $n$ is the lowest cost supplier to $i$ across the varieties. This probability can be derived as:

$$x_{m,in} = Pr \left\{ z_n(q)v_n \tau_{in} t_{in} \leq \min_{\ell \neq n} (z_\ell(q)vc_\ell t_{i\ell}) \right\}, \hfill (7.16)$$

Use the properties of the exponential distribution and (7.15) to arrive at the expression for trade shares:

$$x_{m,in} = \frac{(\kappa_{mn} \tau_{m,in} t_{m,in})^{-\theta_m}}{\sum_{\ell} (\kappa_{m\ell} \tau_{m,i\ell} t_{m,i\ell})^{-\theta_m}}. \hfill (7.17)$$
The same applies to the agricultural sector.