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ESSAYS ON INTERNATIONAL TRADE, WELFARE AND INEQUALITY

This study is based on the doctoral dissertation titled “Essays on International Trade, Welfare and Inequality” selected as the award winning entry for the EXIM Bank BRICS Economic Research Annual Award (BRICS Award) 2018. The dissertation was written by Dr. Zheli He, currently Economist at the Penn Wharton Public Policy Initiative, under the supervision of Professor David E. Weinstein. Dr. He received her doctoral degree in 2017 from the Columbia University, USA.

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EXECUTIVE SUMMARY

How important are the distributional effects of international trade? This has been one of the most central questions pursued by international economists, particularly because much of the public opposition towards increased openness is due to the belief that welfare changes are unevenly distributed. This study relies on counterfactual analysis and natural experiments to study topics of international trade, welfare and inequality in the context of both developing and developed economies. In particular, the study combines theoretical modeling and empirical analysis to examine the effects of international trade on (1) real wages of individuals within and across regions; (2) within-sector wage dispersion caused by heterogeneous responses of firms with different productivity levels to cheaper imported inputs.

Each of the three chapters contributes to the existing literature by relaxing simplifying assumptions that have proved to be inconsistent with data and exploring new mechanisms that link international trade to inequality.

Chapter 1, "Trade and Real Wages with Demand and Productivity Heterogeneity," presents a general equilibrium model that incorporates the effects of trade liberalization on both an individual's nominal wage and consumer price index. A vast majority of the literature focuses on the income channel, which is its effect on the distribution of nominal wages across workers. A small number of studies consider the expenditure channel, which is its differential impact on consumer price indices. It is well known that the consumption baskets of high-income and low-income consumers look very different. There are only three case studies that have looked at these two channels jointly for individual countries, Argentina, Mexico and India. The study provides a unified framework incorporating both channels by allowing for non-homothetic preferences and worker heterogeneity across jobs. In spite of its many dimensions of heterogeneity at the individual level, the model remains tractable enough that allows the estimation of its key parameters and the performance of counterfactuals.

Chapter 2, "Trade and Real Wage Inequality: Cross-Region Evidence," addresses the following question: what is the impact of trade liberalization on the distribution of real wages in a large cross-section of regions? Trade liberalization affects real-wage inequality through two channels: the distribution of nominal wages across workers and, if the rich and the poor consume different bundles of goods, the distribution of price indices across consumers. Prior work has focused mostly on one or the other of these channels, but no paper has studied both jointly for a large set of regions. Based on the theoretical framework in Chapter 1, the study measures the distributional effects of trade liberalization incorporating both channels for a sample of 40 regions. More specifically, the study parametrizes the model using sector-level trade and production data. Because skill-intensive goods are also high-income elastic in the data, the study finds an intuitive, previously unexplored, and strong interaction between the two channels. According to the counterfactual analysis, trade cost reductions generate dramatically different results for both nominal wage inequality and price index inequality than what previous research has obtained by focusing on either channel alone. The study finds that trade cost reductions decrease the relative nominal wage of the poor and the relative price index for the poor in all regions. On net, real-wage inequality falls everywhere.

Chapter 3, "Imported Inputs and Within-Sector Wage Dispersion," proposes a new mechanism through which trade liberalization affects income inequality within a country: the use of imported inputs. Intuitively, a firm with higher initial productivity is better at using higher quality foreign inputs. This justifies paying the fixed costs for a larger set of imported inputs when input tariff liberalization decreases their relative price. The firm becomes more import intensive, which enhances its productivity advantage. As a result, the firm hires higher quality workers, produces higher quality products and pays higher wages to its workers, increasing within-sector wage dispersion. Both the mean and the dispersion of the distribution of firm productivity, markup and size are found to go up during a period when China reduced its tariffs on imported inputs. More importantly, these results still hold when the subset of firms that survived throughout the sample period, from 1998 to 2007, is considered. In addition, some stylized facts are provided that support the model's prediction that the differential change in the import intensity of firms with different productivity levels explains these patterns. Finally, a partial-equilibrium, heterogeneous-firm model with endogenous imported inputs and labor quality choice that is consistent with these observations is developed.

1. TRADE AND REAL WAGES WITH DEMAND AND PRODUCTIVITY HETEROGENEITY

1.1 Introduction

Trade liberalization may impact individuals' real wages through their nominal wages and their consumer price indices. The changes in their nominal wages depend on changes in producer prices and the jobs in which they are employed, where the jobs of their employment are determined by their characteristics such as age, gender and educational attainment. On the other hand, the changes in their consumer price indices depend on changes in prices of the baskets of goods that they consume, where their consumption baskets are determined by their nominal wages in addition to prices. A vast majority of the literature focuses on the effect of trade on the distribution of nominal wages. A small number of studies consider its differential impact on consumer price indices. This chapter provides a unified framework that incorporates both the *expenditure channel*, i.e., changing consumer price indices, and the *income channel*, i.e., changing nominal wages, to measure the distributional effects of trade in a large cross-section of regions.[1]

The study builds a model combining demand heterogeneity across consumers with productivity heterogeneity across workers. On the demand side, the Almost Ideal Demand System (AIDS) is used to capture non-homothetic preferences. This demand specification allows the consumption baskets of high-income and low-income individuals to differ so that price changes resulting from trade liberalization have a differential impact on their consumer price indices.

On the supply side, an assignment model of the labor market parametrized with a Fréchet distribution is used to capture heterogeneity of workers across jobs. Individuals have comparative advantage across sectors—based on their age, gender and educational attainment— and, therefore, sort into different sectors. Consequently, price changes resulting from trade liberalization have a differential impact on individuals' nominal wages depending on the sectors in which they work.

[1] The study focuses on labor earnings, which are the main source of income for most people.

In addition, individuals are also allowed to differ in their absolute advantage such that labor groups differ in their average productivity and, therefore, have different nominal wages regardless of individuals' sectoral choices.[2] This assumption generates a potential link between the skill distribution and the wage distribution and, as a result, a potential correlation between the changes in individuals' nominal wages and the changes in their consumer price indices.

A vast body of research has examined the impact of trade on the distribution of earnings across workers. Most recently, Galle et al. (2015) develop the notion of "risk-adjusted gains from trade" to evaluate the full distribution of welfare changes in one measure which generalizes the specific-factors intuition to a setting with endogenous labor allocation. Similarly, this study focuses on changes in relative nominal wages across labor groups that result from changes in relative demand across sectors driven by international trade.[3] There is a small number of studies that have considered price indices as a channel through which trade liberalization can affect inequality. For example, Fajgelbaum and Khandelwal (2016) develop a methodology to measure the unequal gains from trade through the expenditure channel using only aggregate statistics. This study extends this approach to incorporate the differential impact of trade liberalization on individuals' nominal wages. In contrast, Faber (2014) exploits barcode level microdata from the Mexican Consumer Price Index and studies the relative price effect of NAFTA on the differential change in the cost of living between rich and poor households. Fally and Faber (2016) use detailed matched U.S. home and store scanner microdata to explore the implications of firm heterogeneity for household price indices across the income distribution. This study complements the existing literature by incorporating both the expenditure and the income channels as well as their interaction in a unified framework to analyze the heterogeneous impact of counterfactual trade shocks across individuals in a large set of regions.

[2] Workers in a labor group share the same observable characteristics such as age, gender and educational attainment.

[3] See also Adão (2015), Burstein et al. (2015) and Dix-Carneiro and Rafael (2015). Some of the mechanisms that have been studied in the literature linking international trade to inequality through the earnings channel have not been incorporated. For example, Yeaple (2005), Verhoogen (2008), Bustos (2011), Burstein and Vogel (2016) and Bloom et al. (2015) show that trade liberalization increases the measured skill bias of technology by reallocating resources from less to more skill-intensive firms within industries and/or inducing firms to increase their skill intensity. A major difficulty is the lack of a comprehensive, matched employer-employee dataset in many regions that covers the period of rising inequality, which is usually confidential. In addition, these papers highlight the role of firms because the standard neoclassical theory of trade is inconsistent with the empirical finding that nominal wage inequality goes up everywhere in response to trade liberalization. This study shows that in a neoclassical setting, non-homothetic preferences allow the model to be fully consistent with the data. Therefore, it becomes an open question which mechanism is more important.

There are only three case studies that have looked at these two channels jointly.[4] Porto (2006) studies the distributional effects of Mercosur, a regional trade agreement among Argentina, Brazil, Paraguay and Uruguay, during the 1990s. Nicita (2009) extends Porto's approach by adding a link from trade policy to domestic prices and studies the trade liberalization that took place in Mexico during the period 1990-2000. Marchand (2012) allows the tariff pass-through to differ across geographical regions and studies the trade reforms in India between 1988 and 2000. The structure of the model in this study allows the estimation of the effects for more regions. By looking at a wide range of regions, it is able to identify general patterns across regions with different characteristics. It is also able to conduct model-based counterfactuals of different trade shocks which are important for policymakers. In addition, as critiqued in Goldberg and Pavcnik (2007), the predictions of these papers depend in a crucial way on estimates of the degree of pass-through from trade policy changes to product prices as well as the wage-price elasticities. These are difficult to estimate consistently with time-series data on wages and prices in a setting when many other policies change contemporaneously with trade.

1.2 The Model

1.2.1 The Environment

The study considers an economy with N regions and J final good sectors. Each good is defined as a sector-region of origin pair. Within any (j,n), output is homogeneous, and the market is perfectly competitive. In region n, there is a continuum of heterogeneous workers with measure L^n. They are grouped into a finite number of types with measure L^n (λ) based on observable characteristics: age, gender and education. It is assumed that types are mutually exclusive.

1.2.2 Definition of Welfare Change

Consider home region h. Trade liberalization induces a set of infinitesimal changes in log prices and log wages. The local welfare change of individual z is defined as the equivalent variation associated with this set of changes.[5] An individual's welfare is affected in two ways. The first is the change

[4] Atkeson and Burstein (2008) draw on a new collection of Mexican microdata to estimate the effect of foreign supermarket entry on household welfare. They do consider both the price index effect and the income effect, but focus only on the gains from retail FDI.

[5] Please refer to Appendix A.1 for the derivation of the local welfare change as the equivalent variation.

in their cost of living resulting from the changes in prices, which is referred to as the expenditure effect. Specifically, it is the price changes applied to the pre-shock expenditure shares. A decrease in prices reduces the cost of living, and therefore increases their welfare. The second is the change in their nominal wage, which is referred to as the income effect.

The local welfare change of individual *z* can be further decomposed into three components. That is, the total effect is the sum of the aggregate expenditure effect, the individual expenditure effect and the income effect. The aggregate expenditure effect can be thought of as the impact of trade liberalization on the cost of living under homothetic preferences, where the ratios of goods demanded by consumers depend only on relative prices, not on income or scale. This effect is the same across all individuals within a region *h*. On the other hand, the individual expenditure effect implies that if individual *z* spends more on good (*j,n*), then the price decrease of that good increases their welfare by a larger amount.

$$\widehat{u_z} = E^h + \widehat{\psi_z} + \widehat{w_z}$$

1.2.3 Non-homothetic Preferences

The Almost-Ideal Demand System (AIDS) is used to capture the non-homotheticity in consumer preferences. It gives an arbitrary first-order approximation to any demand system and satisfies the axioms of order, aggregates over consumers without invoking parallel linear Engel curves, is consistent with budget constraints, and is simple to estimate. The AIDS allows consumption baskets of high-income and low-income individuals to differ so that price changes resulting from trade liberalization can have a differential impact on their consumer price indices. It belongs to the family of Log Price-Independent Generalized Preferences defined by the following indirect utility function:

$$v\left(w_z, \mathbf{p}^h\right) = F\left[\left(\frac{w_z}{a\left(\mathbf{p}^h\right)}\right)^{1/b\left(\mathbf{p}^h\right)}\right]$$

where $F[\cdot]$ is a continuous, differentiable, and strictly increasing function.

The AIDS is the special case that satisfies:

$$
\begin{aligned}
a\left(\mathbf{p}^h\right) &= \exp\Bigg\{\underline{\alpha} + \sum_j \sum_n \alpha^h_{(j,n)} \ln p^h_{(j,n)} + \\
&\quad \frac{1}{2}\sum_j \sum_n \sum_{j'} \sum_{n'} \gamma_{(j,n)(j',n')} \ln p^h_{(j,n)} \ln p^h_{(j',n')}\Bigg\} \\
b\left(\mathbf{p}^h\right) &= \exp\left\{\sum_j \sum_n \beta_{(j,n)} \ln p^h_{(j,n)}\right\}
\end{aligned}
$$

where $a(p^h)$ is a homothetic price aggregator which captures the cost of a subsistence basket of consumption goods. $\underline{\alpha}$ is the outlay required for a minimal standard of living, when prices are unity. $\alpha^h_{(j,n)}$ is importer *h*'s taste for good (j,n). $\gamma_{(j,n)(j',n')}$ is the cross elasticity between two goods (*j*,*n*) and (j', n'). $b(p^h)$ is a non-homothetic price aggregator which captures the relative price of high-income elastic goods. Goods for which $\beta_{(j,n)}$>0 have positive income elasticity, while goods for which $\beta_{(j,n)}$<0 have negative income elasticity. For AIDS to be a proper demand system, the following parametric restrictions need to be satisfied:[6]

$$
\begin{aligned}
\sum_j \sum_n \alpha^h_{(j,n)} &= 1 \\
\sum_j \sum_n \beta_{(j,n)} &= 0 \\
\sum_j \sum_n \gamma_{(j,n)(j',n')} &= 0 \quad \forall \\
\gamma_{(j,n)(j',n')} &= \gamma_{(j',n')(j,n)} \quad \forall (j,n)
\end{aligned}
$$

Applying Shephard's Lemma to the indirect utility function, the individual expenditure shares can be derived as follows:

$$
\begin{aligned}
s^z_{(j,n)} &= s_{(j,n)}\left(w_z, \mathbf{p}^h\right) \\
&= \alpha^h_{(j,n)} + \sum_{j'} \sum_{n'} \gamma_{(j,n)(j',n')} \ln p^h_{(j',n')} + \beta_{(j,n)} \ln\left(\frac{w_z}{a\left(\mathbf{p}^h\right)}\right)
\end{aligned}
$$

[6] Under these constraints, the budget shares equations share the properties of a demand function, that is, they are homogeneous of degree 0 in prices and total expenditure, sum of budget shares add up to 1, and they satisfy the symmetry of the Slutsky matrix.

According to this equation, if individuals have relatively low nominal wages, then they spend relatively more on low-income elastic goods. Under the AIDS, the market can be described by the behavior of a representative consumer with the inequality-adjusted average nominal wage, which depends on the average nominal wage in region h and the Theil index, a measure of inequality within a region. It is therefore straightforward to derive the aggregate expenditure shares in region *h*:

$$\begin{aligned} S^h_{(j,n)} &= s_{(j,n)}\left(\tilde{w}^h, \mathbf{p}^h\right) \\ &= \alpha^h_{(j,n)} + \sum_{j'}\sum_{n'} \gamma_{(j,n)(j',n')} \ln p^h_{(j',n')} + \beta_{(j,n)} \ln\left(\frac{\tilde{w}^h}{a\left(\mathbf{p}^h\right)}\right) \end{aligned}$$

Similarly, adjusted for the price level, if region *h* has higher inequality-adjusted average nominal wage, either because of higher average nominal wage or higher inequality, then it spends relatively more on high-income elastic goods.

Intuitively, for an individual *z* who has lower nominal wage relative to the representative consumer in the region, if the price of a low-income elastic good goes down, they are better off and vice versa. Note that it is not required to observe individual *z*'s expenditure share on each good (*j,n*) in order to compute the change in their consumer price index.

The global welfare change of individual *z* under the AIDS between an initial scenario under trade and a counterfactual scenario can be derived as the following:

$$\underbrace{u_z^{tr\rightarrow cf}}_{\text{total effect}} = \underbrace{\left(\frac{E^h_{cf}}{E^h_{tr}}\right)}_{\text{agg. exp. eff.}} \underbrace{\left(\frac{\psi_z^{cf}}{\psi_z^{tr}}\right)}_{\text{ind. exp. eff.}} \underbrace{\left(\frac{w_z^{cf}}{w_z^{tr}}\right)}_{\text{income effect}}$$

If $u_z^{tr\rightarrow cf} < 1$, individual *z* is worse off after the change and vice versa.

1.2.4 Heterogeneous Labor with Comparative Advantage across Sectors

The supply-side specification in this study allows for heterogeneous labor with comparative advantage across sectors so that different labor types sort into different sectors. As a result, price changes resulting from trade liberalization can have a differential impact on their nominal wages. An assignment model of the labor market parametrized with a Fréchet distribution is used. In this environment, workers with different unobservable characteristics but identical observable characteristics may be allocated to different sectors in a competitive equilibrium.[7] In particular, an arbitrary worker draws a vector of efficiency units across different sectors from a Fréchet distribution.[8] Within-type dispersion of efficiency units across sectors is governed by its shape parameter. Worker z inelastically supplies $\epsilon\ (z;\ j)$ efficiency units of labor if they choose to work in sector j.

Production requires only one factor, labor.[9&10&11]The production function in region h, sector j, using l efficiency units of labor type λ is:[12]

$$y^h\,(l;\lambda,j) = A^h(\lambda)T(\lambda, j)\ l$$

[7] It is assumed that the labor market is perfectly competitive, that is, there is no friction. Dix-Carneiro and Rafael (2015) finds that workers' median costs of switching sectors range from 1.4 to 2.7 times individual annual average wages, but these vary tremendously across individuals with different observable characteristics. For example, female, less educated, and older workers face substantially higher costs of switching as a fraction of individual wages. This increases the probability of unemployment of the low-skilled, and biases the gains from trade towards the high-skilled and high-income.

[8] Fréchet distributions of productivity shocks across factors have been imposed in the recent closed economy models of Lagakos and Waugh (2013) and Hsieh et al. (2013) as well as the open economy models of Burstein et al. (2015), Costinot et al. (2016), and Feenstra and Romalis (2014). Sector and region characteristics are assumed to be perfectly observed by the econometrician, but factor characteristics are not. See Costinot and Vogel (2015) for a detailed discussion.

[9] For simplicity, capital is abstracted from the production function. Capital may matter for two reasons. First, it may generate comparative advantage across sectors. This is very similar to introducing Hicks-neutral capital, where capital is more important in some sectors than others. That would generate technological differences at the region-sector level. Capital reallocation reinforces labor reallocation in response to trade liberalization. Second, capital may be differentially complementary to different types of labor. In that case, there is a large number of cross elasticities that needs to be estimated, which is challenging.

[10] Complementarity between different types of equipment and heterogeneous workers across sectors as in Burstein et al. (2015) are not featured in this study because of a lack of data to compute the share of total hours worked by each labor group that is spent using different equipment types across sectors.

[11] The model is static, and therefore, does not take any stand on the accumulation of skills and capital in response to trade liberalization. Each region's endowments of skills and capital are taken as given for now, but it would be great to introduce dynamics to the framework.

[12] The model also features Ricardian-type region-sector productivity. Appendix A.2 demonstrates the specialization of skill-abundant regions in skill-intensive sectors.

$A^h(\lambda)$ is the productivity of type λ workers in region h, and $T(\lambda, j)$ is the productivity of type λ workers who choose to work in sector j. $A^h(\lambda)$ captures the absolute advantage of type λ workers in region h. $T(\lambda, j)$ captures the comparative advantage of type λ workers in sector j. Consider the partial equilibrium in which output prices are given. Perfect competition and free entry entail that the per efficiency unit wage of workers of labor type λ working in sector j in region h is the product of the output price and their absolute and comparative advantage. Workers choose the sector that maximizes their labor earnings, which are the product of their draw of efficiency units and per efficiency unit wage:

$$w_z = \max w_z(j) = \epsilon(z; j) \cdot x^h(\lambda, j) j$$

The Fréchet distribution implies that the probability of a type λ worker choosing to work in sector j in region h is:

$$\pi^h(\lambda, j) = \frac{\left[p^h_{(j,h)} A^h(\lambda) T(\lambda, j)\right]^{\theta(\lambda)}}{\sum_{j' \in \mathcal{J}} \left[p^h_{(j',h)} A^h(\lambda) T(\lambda, j')\right]^{\theta(\lambda)}} = \frac{x^h(\lambda, j)^{\theta(\lambda)}}{x^h(\lambda)^{\theta(\lambda)}}$$

With a higher $\theta(\lambda)$, which implies that there is less dispersion of efficiency units across sectors, a change in price or a change in productivity affects the factor allocation even more.

As a result, the worker sorting pattern is determined by comparative advantage:

$$\frac{\left[\frac{\pi^h(\lambda',j')}{\pi^h(\lambda',j)}\right]^{\frac{1}{\theta(\lambda')}}}{\left[\frac{\pi^h(\lambda,j')}{\pi^h(\lambda,j)}\right]^{\frac{1}{\theta(\lambda)}}} = \frac{\left[\frac{T(\lambda',j')}{T(\lambda',j)}\right]}{\left[\frac{T(\lambda,j')}{T(\lambda,j)}\right]}$$

If type λ' workers (relative to type λ workers) have a comparative advantage in sector j' (relative to sector j), then they are relatively more likely to sort into sector j', adjusted for potentially different values of $\theta(\lambda)$ and $\theta(\lambda')$. For larger $\theta(\lambda')$, that is, less dispersion in efficiency units among type λ' workers, it is even more likely for them to sort into sector j', in which they have a comparative advantage.

As a result of this specification of the labor market, labor earnings also follow a Fréchet distribution with the scale parameter being the average per efficiency unit wage of a given labor type across the sectors, along with the dispersion parameter, $\theta(\lambda)$.[13] The average nominal wage and the Theil index in region h can also be expressed in terms of these parameters.

1.2.5 General Equilibrium

In the general equilibrium, output prices are determined by the market clearing conditions:

$$\sum_{\lambda} y^h \left(L^h(\lambda)\,\pi^h(\lambda, j)\,; \lambda, j\right) = \sum_{n} \tau^n_{(j,h)} D^n_{(j,h)} \quad \forall j \in \mathcal{J}$$

$\tau^n_{(j,h)}$ is the bilateral trade costs between export region *h* and import region n in sector j. Since these output prices enter both the demand side and the supply side nonlinearly, the Gauss-Jacobi algorithm, an iterative method, is applied to solve the system of market clearing equations numerically.[14] The Implicit Function Theorem is appealed to show that the price equilibrium that is found numerically is locally isolated as a function of the parameters.[15] That is, in response to a small perturbation, if there exists an equilibrium, then the system stays in the neighborhood of that equilibrium. No quantitative evidence of multiple equilibria are found.[16]

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[13] Burstein and Vogel (2016) find that the wage distribution implied by the assumption of Fréchet distributions is a good approximation to the observed distribution of individual wages.

[14] The existence of an equilibrium is demonstrated numerically.

[15] Please refer to Appendix A.3 for a brief discussion of the Gauss-Jacobi Algorithm and the local property of the equilibrium.

[16] Multiple starting points are tried, and the system always converges to the same equilibrium. The study has not proven either existence or uniqueness analytically. It is a complicated model with interactions, and is not mapped neatly into the class of models considered in Alvarez and Lucas (2007).

1.3 Conclusion

Trade liberalization may impact individuals' real wages through their nominal wages and their consumer price indices. The changes in their nominal wages depend on changes in producer prices and the jobs in which they are employed, where the jobs of their employment are determined by their characteristics such as age, gender and educational attainment. On the other hand, the changes in their consumer price indices depend on changes in prices of the baskets of goods that they consume, where their consumption baskets are determined by their nominal wages in addition to prices. A vast majority of the literature focuses on the effect of trade on the distribution of nominal wages. A small number of studies consider its differential impact on consumer price indices. This study provides a unified framework that incorporates both the *expenditure channel*, i.e., changing consumer price indices, and the *income channel*, i.e., changing nominal wages, to measure the distributional effects of trade in a large cross-section of regions.

In order to allow price indices to vary across consumers within a region, demand heterogeneity is required. The Almost Ideal Demand System (AIDS) is used to capture non-homothetic preferences. This demand specification allows the consumption baskets of high-income and low-income individuals to differ so that price changes resulting from trade liberalization have a differential impact on their consumer price indices. In order to allow nominal wages to vary across workers within a region, productivity heterogeneity is required. An assignment model of the labor market is used to capture heterogeneity of workers across jobs. Individuals have comparative advantage across sectors and, therefore, sort into different sectors. Consequently, price changes resulting from trade liberalization have a differential impact on individuals' nominal wages depending on the sectors in which they work.

This model with demand heterogeneity across consumers and productivity heterogeneity across workers can be used to quantify the distributional effects of trade liberalization for a wide range of regions. By looking at a large set of regions, the study is able to identify general patterns across regions with different characteristics. The study is also able to conduct model-based counterfactuals of different trade shocks, which are important for policymakers.

2. TRADE AND REAL WAGE INEQUALITY: CROSS - REGION EVIDENCE

2.1 Introduction

Trade liberalization affects real wage inequality through two channels: the distribution of nominal wages across workers and, if the rich and the poor consume different bundles of goods, the distribution of price indices across consumers. Prior work has focused mostly on one or the other of these channels, but no paper has studied both jointly for a large set of regions. Based on the theoretical framework in Chapter 1, this chapter measures the distributional effects of trade liberalization incorporating both channels for a sample of 40 regions. Because skill-intensive goods are also high-income elastic in the data, the study finds an intuitive, previously unexplored, and strong interaction between these two channels. According to the counterfactual analysis, trade cost reductions generate dramatically different results for both nominal wage inequality and price index inequality than what previous research has obtained by focusing on either channel alone.

In isolation, these two channels have well-understood implications. Shutting down the expenditure channel, the study finds that the income channel benefits the poor more than the rich in low-income regions and the rich more than the poor in high-income regions. This is consistent with standard factor proportions theory in which a reduction in trade costs raises the relative nominal wage of the abundant factor in every region, benefiting the unskilled (and poor) workers in skill-scarce regions that are low income and the skilled (and rich) workers in skill-abundant regions that are high income. Shutting down the income channel, the study finds that the expenditure channel benefits the poor more than the rich in every region and more so in high-income regions. Intuitively, lower trade costs increase real incomes and, therefore, decrease the relative demand for and the relative price of low-income elastic goods.

Because low-income consumers spend more on these goods, they benefit relatively more. The expenditure channel benefits the poor relatively more in high-income regions because these regions are net importers of low-income elastic goods.

These two channels do not work in isolation. Studying either channel in the absence of the other leads to profoundly biased results qualitatively and quantitatively. Specifically, their interaction implies that the income channel benefits the rich in every region, which is consistent with a large body of empirical evidence; see e.g. Goldberg and Pavcnik (2007). Intuitively, when both channels are active, lower trade costs increase real incomes and, therefore, decrease the relative demand for and the relative price of low-income elastic goods as discussed above.[17] Since the poor disproportionately produce unskilled-intensive goods, which are low-income elastic, their relative nominal wage falls in every region. This effect is absent when only the income channel is active. Moreover, the interaction of these two mechanisms also implies that the poor's relative benefit from the expenditure channel is magnified in every region. Intuitively, because nominal wage inequality rises in every region, as just described, the relative demand for and the relative price of low-income elastic goods fall even further, reducing the relative price index for the poor in every region. This effect is absent when only the expenditure channel is active because nominal wage inequality is constant in that case.[18]

The study parametrizes the model for a sample of 40 regions (27 European countries and 13 other large regions) and 35 sectors using a range of datasets including the World Input-Output Database (WIOD) and the Integrated Public Use Microdata Series, International (IPUMS-I). WIOD provides information on bilateral trade flows and production data.[19] A sectoral non-homothetic gravity equation is derived that allows the estimation of the elasticity of substitution and the income elasticity of goods as follows.[20] First, the elasticity of substitution is estimated by projecting regions' sectoral expenditure shares on trade costs.

[17] Alternative models can also generate the increase in the skill premium, for example, a close-economy macroeconomic model where there is a uniform increase in productivity with non-homothetic preferences. Caron et al. (2014) find that it raises wages of skilled workers significantly, increasing the nominal wage inequality at equilibrium. This study focuses on the impact of a decrease in trade costs as an explanation.

[18] There are other types of gains from trade. For example, the access to more product varieties makes everyone better off. Fajgelbaum and Khandelwal (2016) find that low-income consumers spend relatively more on sectors that are more traded, where high-income consumers spend relatively more on services, which are among the least internationally traded sectors. As a result of trade liberalization, there is a bigger increase in product varieties in the sectors that have a low-income elasticity, which benefits the poor even more. On the other hand, Fally and Faber (2016) find that changes in product varieties affect the price indices of rich and poor households asymmetrically. More product entry benefits richer households slightly more due to higher estimated love of variety. Consequently, it becomes an empirical question which factor dominates.

[19] One important feature of the WIOD is that it includes the input-output transactions of a region with itself. Typically, the domestic market accounts for the large majority of demand for most production.

[20] The sectoral non-homothetic gravity equation based on the AIDS was first derived in Fajgelbaum and Khandelwal (2016). However, their model assumptions imply that the change in income is 0 for all consumers.

Second, the income elasticity of each good is estimated using the following insight: if high-income or more unequal regions spend relatively more on a good, then it is inferred that this good is high-income elastic.

IPUMSI provides publicly available nationally representative survey data for 82 regions that are coded and documented consistently across regions and over time. It reports individual level information including age, gender, educational attainment, labor income and sector of work. This rich database enables the estimation of the Fréchet dispersion parameter of the within-group distribution of efficiency units across sectors which determines the extent of worker reallocation and, thus, the responsiveness of group average wages to changes in sectoral output prices. In addition, the comparative advantage of different labor groups across sectors is estimated based on observed worker sorting patterns. Intuitively, if a worker type (relative to another worker type) is more likely to sort into a sector (relative to another sector), then it is inferred that they are relatively more productive in that sector. Using the estimates of group average wages and other parameters, the absolute advantage of different labor groups can also be backed out.

With these parameter estimates, two counterfactual analyses are conducted to quantify the distributional effects of trade liberalization. To demonstrate how the model works, the study begins with a simple counterfactual exercise in which a 5% reduction in all bilateral trade costs is considered. The study finds that within each region, as one moves up the initial nominal wage distribution, gains decline. Specifically, moving up from one decile to the next reduces gains by 0.1 percentage point: the bottom 10th percentile experiences a real wage gain that is larger than the top 10th percentile in every region, and the difference is 0.8 percentage points in the average region. The study obtains the result that the poor gain relative to the rich in spite of the fact that it finds the opposite result for nominal wages. In the average region, the bottom 10th percentile see their nominal wages decrease by 0.2 percentage points relative to the top 10th percentile. Hence, the reduction in the poor’s relative price index must fall substantially. In the average region, the bottom 10th percentile see their consumer price indices decrease by 1 percentage point more than the top 10th percentile.

The theoretical framework in Chapter 1 also allows the re-examination of the impact of a significant increase in U.S. manufacturing imports from China on U.S. real-wage inequality while accounting for both channels and their interaction.[21 & 22]

The study considers a uniform reduction in trade costs between the U.S. and China that would yield a $1000 per U.S. worker increase in Chinese manufacturing imports.

The study finds that individuals whose nominal wages are at the 10th percentile of the initial distribution see a further 0.35 percentage point reduction in their consumer price indices compared to the representative consumer, while individuals whose nominal wages are at the 90th percentile see their consumer price indices decrease by 0.1 percentage point less than the representative consumer. This result arises because Chinese manufacturing goods are low-income elastic and, consequently, their lower prices benefit more the poor individuals who spend relatively more on these goods. Although the former see a bigger decline in their nominal wages (0.13% vs. 0.11%) because they are more likely to work in manufacturing sectors that are in direct competition with cheaper Chinese imports, this income effect is more than offset by their much lower consumer price indices. Rising Chinese import competition increases the real wages of the poor by 0.43 percentage points more than those of the rich in the U.S.

The remainder of this chapter proceeds as follows. Section 2.2 contains a description of the data, and estimation strategy and results are gathered in Section 2.3. In Section 2.4, counterfactual results are discussed. Section 2.5 concludes.

2.2 Data

For the demand-side estimation, the study uses mainly the World Input-Output Database (WIOD), which provides information on bilateral trade flows and production data for 40 regions (27 European countries and 13 other large regions) and 35 sectors in the economy. It also distinguishes between final consumption and intermediate uses.[23] World Input-Output Table looks like **Figure 2.1**:

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[21] Autor et al. (2013), Autor et al. (2014) and Acemoglu et al. (2016) study the impact of increased Chinese import competition on employment and earnings of U.S. workers by comparing more affected industries and local labor markets to less affected ones but have no implications at the aggregate level.

[22] Another interesting counterfactual to consider is the Trans-Pacific Partnership (TPP). The framework can be used to simulate the aggregate and distributional effects of this trade agreement for each of the participating countries.

[23] The UN Comtrade Database is not used because it does not have information on the input-output transactions of a region with itself.

Figure 2.1: Schematic Outline of a World Input-Output Table (WIOT)

			Use by country-industries							Final use by countries			Total use
			Country 1			...	Country M			Country 1	...	Country M	
			Industry 1	...	Industry N	...	Industry 1	...	Industry N		...		
Supply from country-industries	Country 1	Industry 1											
		...											
		Industry N											
	......												
	Country M	Industry 1											
		...											
		Industry N											
Value added by labour and capital													
Gross output													

For the supply-side estimation, the study uses mainly the Integrated Public Use Micro data Series, International (IPUMS-I), which provides publicly available nationally representative survey data for 82 regions that are coded and documented consistently across regions and over time and individual-level data with labor incomes and worker characteristics. The workers in IPUMS-I dataset are divided into 18 disjoint groups by age (15-24, 25-49 and 50-74), gender (male and female) and educational attainment (ED0-2, less than primary, primary and lower secondary education; ED3-4, upper secondary and post-secondary non-tertiary education; ED5-8, tertiary education).

2.3 Parameterization

2.3.1 Supply-side Parameters

On the supply side, the study needs to estimate $\theta(\lambda)$, the worker type specific Fréchet dispersion parameter; $L^h(\lambda)/L^h$, the fraction of type λ workers in region h; $A^h(\lambda)$, the productivity of type λ workers in region h and $T(\lambda, j)$, the productivity of type λ workers who choose to work in sector j.

To estimate the worker type specific Fréchet dispersion parameter, $\theta(\lambda)$, the methodology in Lagakos and Waugh (2013) and Hsieh et al. (2013) is followed and the moments of the empirical distribution of within type worker wages are matched.

The sample is restricted in the following way: workers who are younger than 15 years old, are self-employed or work part-time (<30 hours per week), do not report positive labor earnings, or have missing information on age, sex or education are dropped. The top and bottom 1% of earners are also dropped to remove potential outliers, and to minimize the impact of potential cross-region differences in top-coding procedures. All calculations in the analysis are weighted using the applicable sample weights. w_z is measured as the annual labor earnings; $\epsilon(z;\ j)$ captures both the hours worked and efficiency units of worker z who chooses to work in sector j; $\theta(\lambda)$ reflects dispersion in both hours worked and efficiency units of type workers; $L^h(\lambda)$ is the headcount of type λ workers.

IPUMS-I is used to estimate $\theta(\lambda)$ for 16 regions.[24] Since the estimates of $\theta(\lambda)$ are very close across the 16 regions for each labor type, the average of these estimates is used for all regions, and it is assumed that $\theta(\lambda)$ does not change over time. $x^h(\lambda)$ for the 16 regions can also be backed out. Since all earnings data in IPUMS-I are in local currency units, the official exchange rate (LCU per US$, period average) from the World Bank is used to convert all values to US$. Output-side real GDP per capita is found to have strong explanatory power for $x^h(\lambda)$, so the predicted values of $x^h(\lambda)$ for the rest of the regions are used.[25]

Since IPUMS-I does not provide information on $L^h(\lambda)/L^h$ for all of the 40 regions, the following complementary datasets are used. First, Eurostat, which provides information on the full-time and part-time employment by age, gender and educational attainment. It covers the 27 European countries in the WIOD. Second, UNdata, which has information on population 15 years of age and over, also by age, gender and educational attainment, for Russia, Australia, Korea and China. This dataset comes from UNSD Demographic Statistics–United Nations Statistics Division. Third, National Statistics, Republic of China (Taiwan) and finally, Population Statistics of Japan.

In order to estimate the sector-level non-homothetic gravity equation, which is explained in detail in the next section, the inequality-adjusted average nominal wage of each region needs to be computed, which requires an estimate of its average nominal wage as well as its Theil index.

[24] The list of regions can be found in Appendix B.1.

[25] The data on output-side real GDP at chained PPPs (in millions of 2005 US$) and population are obtained from the Penn World Tables.

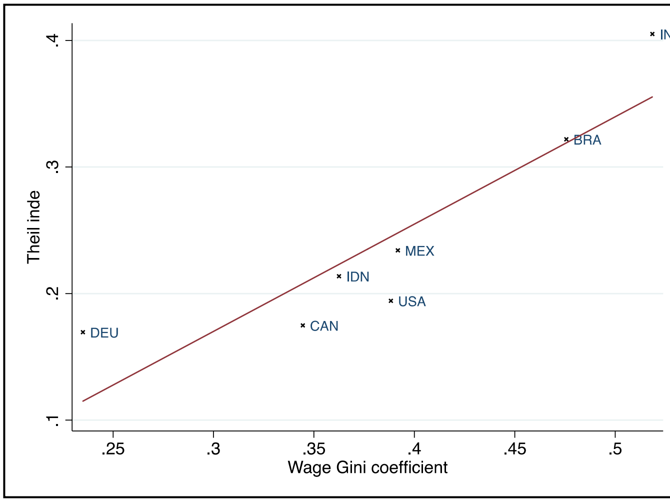
Table 2.1 reports the estimates of the average labor earnings and the Theil index for the 40 regions. They are estimated for the years 2005, 2006 and 2007, and then the average is taken.

Table 2.1: Average Labor Earnings and Theil Index

Region	Theil	Avg Labor Earnings	Region	Theil	Avg Labor Earnings
AUS	0.17	35871	IRL	0.18	45164
AUT	0.18	31585	ITA	0.17	25381
BEL	0.17	31446	JPN	0.17	30438
BGR	0.19	7196	KOR	0.18	23422
BRA	0.32	2835	LTU	0.17	11927
CAN	0.17	37134	LUX	0.17	60919
CHN	0.34	1661	LVA	0.18	9889
CYP	0.18	17773	MEX	0.23	3813
CZE	0.17	18342	MLT	0.20	13412
DEU	0.16	33901	NLD	0.17	39566
DNK	0.17	34748	POL	0.17	11096
ESP	0.19	25098	PRT	0.19	14326
EST	0.17	14544	ROU	0.19	6365
FIN	0.17	32274	RUS	0.18	11210
FRA	0.18	27794	SVK	0.17	12936
GBR	0.18	31318	SVN	0.17	19767
GRC	0.18	20335	SWE	0.17	33596
HUN	0.17	12821	TUR	0.21	6884
IDN	0.20	1378	TWN	0.21	21729
IND	0.40	737	USA	0.19	41898

Recall that the Theil index measures the level of inequality within a region, which in the framework is the dispersion in labor incomes. Since the Theil indices are calculated using only the labor earnings of the population aged between 15 and 74, IPUMS-I is also used to construct alternative measures of wage Gini coefficients based on three different methods that are widely used in the literature.

Figure 2.2: Wage Gini Coefficient Calculated Using IPUMS-I



The three methods generate very similar estimates and **Figure 2.2** demonstrates that the model-implied Theil indices perform very well against the Jasso and Deaton measure. Their correlation is significantly positive at 0.89.

Figure 2.3 plots the model-implied Theil indices for all of the 40 regions against the Gini coefficients reported in the World Income Inequality Database that are computed using all sources of income. The two measures are still positively correlated and the correlation is around 0.61. In the right panel, the three potential outliers are excluded and the correlation coefficient remains positive and is around 0.55.

Figure 2.3: Theil Index

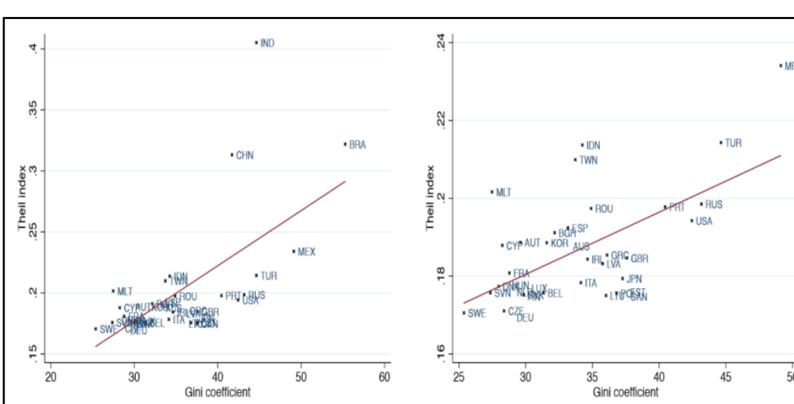
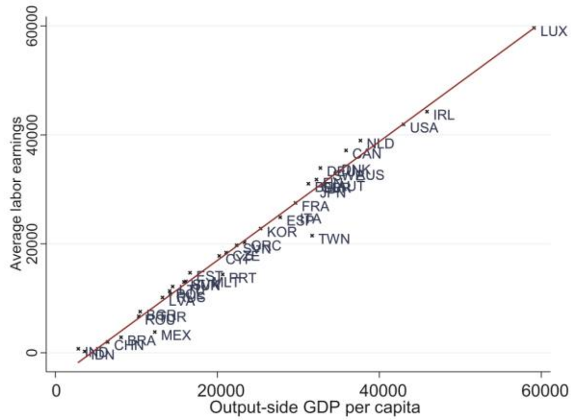


Figure 2.4 plots the model-implied labor earnings per capita against output-side GDP per capita. The measure of income per capita tracks the data very well. These parameter implications provide evidence that model assumptions on the supply side are reasonable.

Figure 2.4: Average Labor Earnings



As discussed above, the worker sorting pattern can be used to parametrize *T* (λ, j). 52 normalizations are required. Data on $\pi^h(\lambda, j) = L^h(\lambda, j)/L^h(\lambda)$ are also needed, where $L^h(\lambda, j)$ is the headcount of type λ workers in region *h* that choose to work in sector *j*. Since there is no information on $L^h(\lambda, j)$ in Eurostat or UN data, data on the regions that are available in IPUMS-I are used to compute *T* (λ, j) and then the average of the estimates for all of the regions is used.[26] Given the specified normalizations,

$$\frac{\pi(\lambda', j)}{\pi(\lambda, j)} = \frac{T(\lambda', j)^{\theta(\lambda')}}{T(\lambda, j)^{\theta(\lambda)}}$$

Figure 2.5 plots this ratio aggregating the 18 labor groups into three broad categories based on educational attainment against an estimate of the skill intensity of each sector, which matches the share of hours worked in that sector by workers with a completed tertiary degree in the U.S.[27]

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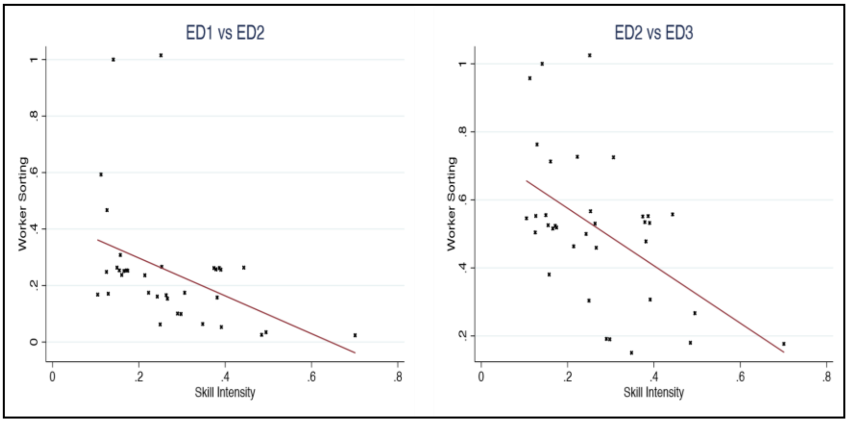
[26] This restriction implies, for example, a U.S. and a Chinese female worker who are 25-year-old and college educated are both twice as productive in health care as in mining. Because of data limitations, *T* (λ,j) cannot be estimated for every region. This restriction is reasonable and does well in capturing the systematic relationship between the different labor types and the sectors that they sort into.

[27] ED1 corresponds to less than primary, primary and lower secondary education; ED2 corresponds to upper secondary and post-secondary non-tertiary education; ED3 corresponds to tertiary education.

The correlation coefficients are -0.41 and -0.52, respectively. These graphs illustrate that workers with less education are more likely to work in unskilled-intensive sectors. This implies that a decline in the relative price of goods in unskilled-intensive sectors decreases the relative nominal wage of unskilled workers.[28]

Figure 2.5: Worker Sorting



To estimate $A^h(\lambda)$, the productivity of type λ workers in region h, a first-order approximation of the following equation at $p = 1$, $T = 1$ is taken:[29]

$$x^h(\lambda) = \left(\sum_j x^h(\lambda, j)^{\theta(\lambda)}\right)^{\frac{1}{\theta(\lambda)}} = \left\{\sum_{j \in \mathcal{J}} \left[p^h_{(j,h)} A^h(\lambda) T(\lambda, j)\right]^{\theta(\lambda)}\right\}^{\frac{1}{\theta(\lambda)}}$$

$$= A^h(\lambda)\left\{\sum_{j \in \mathcal{J}} \left[p^h_{(j,h)} T(\lambda, j)\right]^{\theta(\lambda)}\right\}^{\frac{1}{\theta(\lambda)}}$$

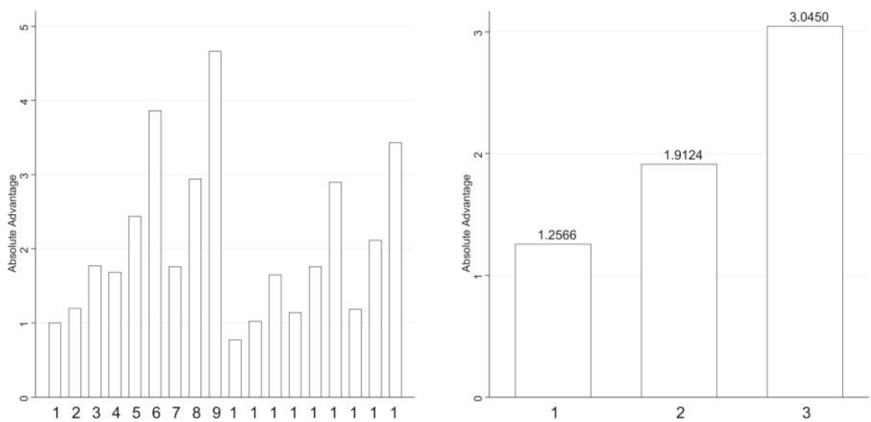
It is assumed that $A^h(\lambda = 1) = 1$ for all h.Figure 2.6 is a bar chart that plots the average $A^h(\lambda)$ across regions for each of the 18 labor groups by age, gender and educational attainment. As expected, for those who are of the same age and gender, the less education one receives, the lower the average estimate of $A^h(\lambda)$. In addition, for those who are of the same gender and have

[28] In partial equilibrium, changes in wages are proportional to changes in output prices, where the weight depends on factor allocation in the initial period. An increase in sector *j*'s output price raises the relative wage of labor groups that disproportionately work in sector *j* in the initial trade equilibrium.

[29] Please see Appendix B.2 for the derivation of the equation used to estimate $A^h(\lambda)$. Please refer to Appendix B.3 for a description of the characteristics of each labor group.

the same level of education, the younger one is, the lower the average estimate of $A^h(\lambda)$. Finally, a female worker is estimated to have lower average $A^h(\lambda)$ than her male counterpart. Zooming in on education, the 18 labor groups are aggregated into three broad categories. The bar chart on the right illustrates that less educated individuals have lower $A^h(\lambda)$ on average regardless of their age and gender. This implies that less educated workers have lower nominal wages regardless of their sectoral choices.

Figure 2.6: $A^h(\lambda)$ and Education



2.3.2 Demand-side Parameters

On the demand side, the study needs to estimate $\underline{\alpha}$, which can be interpreted as the outlay required for a minimal standard of living when prices are unity. 0 is assigned to $\underline{\alpha}$ a priori. The study also needs to estimate the vector of income elasticities and the matrix of cross elasticities as well as the overall taste in region *h* for the goods exported by region *n* in sector *j* independently from prices or income of the importer.

On top of the regularity restrictions imposed by the AIDS, additional assumptions are imposed on the matrix to reduce the number of parameters that are estimated. In words, these assumptions imply that within the same sector, cross elasticities are the same between goods produced by different regions and across sectors, there is no substitution.[30]

[30] Normalization by the number of regions *N* is mainly for notational simplicity and is not necessary.

Under these parametric restrictions, the sectoral non-homothetic gravity equation captures the size of the exporter *n* in sector *j* in the world economy, the differences in tastes across regions for different goods, bilateral trade costs and multilateral resistance and a non-homothetic component. For example, a region with higher average nominal wage or higher level of inequality is predicted to consume more high-income elastic goods.

Following Fajgelbaum and Khandelwal (2016), the differences in taste across regions for different goods are estimated by the product of an exporter fixed effect and region *h*'s expenditure share on sector *j* relative to the world. Since the trade costs between region pairs are not directly observed, bilateral observables are used to proxy them.

To be more specific, it is assumed that importer *h*'s taste for good (j,n), $\alpha^h_{(j,n)}$, can be decomposed into an exporter effect, α_n, a sector effect, α_j, and an importer taste for that sector, ϵ^h_j. Under the additional assumptions, the sectoral expenditure shares become:

$$S_j^h = \sum_n S_{(j,n)}^h = \bar{\alpha}_j^h + \bar{\beta}_j y^h$$

In the absence of non-homotheticity, $\bar{\beta}_j = 0$ for all j. In that case, the upper tier is Cobb- Douglas with fixed expenditure shares. The study further imposes that $\Sigma_{n=1}^N \alpha_n = 1$. It is assumed that bilateral trade costs can be estimated using bilateral distance, common language and border information from CEPII's Gravity database. The homothetic price aggregator is proxied with a Stone index, where the quality-adjusted prices estimated by Feenstra and Romalis (2014) are used. Estimates of the average labor earnings and the Theil index from the supply side are as reported in the last section.

The non-homothetic gravity equation is estimated from the WIOD using average flows between 2005 and 2007 to smooth out any temporary shocks. In the benchmark, expenditure shares are computed as percentages of total expenditure. As a robustness check, expenditure shares are computed as percentages of final consumption expenditure.

Table 2.2 reports the estimates of the cross-substitution elasticities between different suppliers of a good within each sector. Note that the sector-level non-homothetic gravity equations add up to a single-sector gravity equation. The sum of the estimates across sectors is 0.24. It is very close to the estimate in Fajgelbaum and Khandelwal (2016). Estimating a translog gravity equation, Novy (2013) reports a sum of 0.167, while Feenstra and Weinstein (2010) reports a median of 0.19.

Table 2.2: Cross-substitution between Goods

Sector	γ_j- **total**	γ_j- **final**	**Sector**	γ_j- **total**	γ_j- **final**
Agriculture	0.0060	0.0048	Sales, Repair of Motor Vehicles	0.0030	0.0030
Mining	0.0029	0.0008	Wholesale Trade and Commission Trade	0.0115	0.0121
Food, Beverages and Tobacco	0.0086	0.0102	Retail Trade	0.0104	0.0131
Textiles	0.0021	0.0017	Hotels and Restaurants	0.0074	0.0109
Leather and Footwear	0.0004	0.0004	Inland Transport	0.0046	0.0042
Wood Products	0.0013	0.0003	Water Transport	0.0006	0.0001
Printing and Publishing	0.0037	0.0017	Air Transport	0.0013	0.0012
Coke, Refined Petroleum, Nuclear Fuel	0.0045	0.0023	Other Auxiliary Transport Activities	0.0025	0.0015
Chemicals and Chemical Products	0.0068	0.0022	Post and Telecommunications	0.0058	0.0051
Rubber and Plastics	0.0026	0.0006	Financial Intermediation	0.0180	0.0102
Other Non-Metallic Minerals	0.0028	0.0007	Real Estate Activities	0.0179	0.0252
Basic Metals and Fabricated Metal	0.0103	0.0021	Renting of M&Eq	0.0158	0.0058
Machinery	0.0047	0.0048	Public Admin and Defense	0.0166	0.0317
Electrical and Optical Equipment	0.0081	0.0048	Education	0.0067	0.0133
Transport Equipment	0.0058	0.0052	Health and Social Work	0.0103	0.0204
Manufacturing, nec	0.0015	0.0019	Other Community and Social Services	0.0101	0.0143
Electricity, Gas and Water Supply	0.0072	0.0042	Private Households with Employed Persons	0.0003	0.0006
Construction	0.0215	0.0364	**sum**	**0.2433**	**0.2580**

Table 2.3 reports the estimates of the sectoral income elasticities. The corresponding elasticities for food, manufacturing and services are -0.022, -0.0051 and 0.0271, respectively. The service sectors are found to have a higher income elasticity as expected.

Table 2.3: Sectoral Betas

Sector	γ_j- **total**	γ_j- **final**	**Sector**	γ_j- **total**	γ_j- **final**
Agriculture	-0.0128	-0.0117	Sales, Repair of Motor Vehicles	0.0020	0.0022
Mining	-0.0052	-0.0002	Wholesale Trade and Commission Trade	-0.0001	-0.0008
Food, Beverages and Tobacco	-0.0080	-0.0103	Retail Trade	-0.0011	0.0000
Textiles	-0.0034	-0.0024	Hotels and Restaurants	0.0004	0.0016
Leather and Footwear	-0.0005	-0.0004	Inland Transport	-0.0041	-0.0044
Wood Products	-0.0006	0.0002	Water Transport	-0.0008	-0.0012
Printing and Publishing	0.0007	0.0012	Air Transport	0.0003	0.0002
Coke, Refined Petroleum, Nuclear Fuel	-0.0017	0.0004	Other Auxiliary Transport Activities	0.0024	0.0011
Chemicals and Chemical Products	-0.0027	-0.0009	Post and Telecommunications	0.0005	0.0002
Rubber and Plastics	-0.0005	-0.0003	Financial Intermediation	0.0117	0.0032
Other Non-Metallic Minerals	-0.0009	0.0000	Real Estate Activities	0.0059	0.00106
Basic Metals and Fabricated Metal	0.0004	0.0004	Renting of M&Eq	0.0131	0.0016
Machinery	-0.0003	-0.0006	Public Admin and Defense	0.0028	0.0051
Electrical and Optical Equipment	-0.0002	-0.0014	Education	0.0012	0.0026
Transport Equipment	-0.0022	-0.0013	Health and Social Work	0.0072	0.0137
Manufacturing, nec	0.0000	0.0002	Other Community and Social Services	0.0005	0.0013
Electricity, Gas and Water Supply	-0.0004	0.0010	Private Households with Employed Persons	0.0002	0.0004
Construction	-0.0038	-0.0111	**sum**	**0.000**	**0.000**

Figure 2.7 plots the sectoral income elasticity computed from total expenditure and final consumption against the exporter's log average income. The correlation coefficient is about 0.4 using either measure. A positive relationship is found,which implies that high-income regions specialize in the production of high-income elastic goods. This finding is consistent with previous findings in Hallak (2006), Khandelwal (2010), Hallak and Schott (2011) and Feenstra and Romalis (2014). The null hypothesis that all income elasticities are zero is rejected.

Figure 2.8 plots the sectoral income elasticity computed from total expenditure and final consumption against the skill intensity of each sector. Skill-intensive sectors are found to produce goods that are high-income elastic. The correlation coefficient is 0.4 when total expenditure is used to estimate the sectoral income elasticity. This implies that a decline in the relative price of low-income elastic goods from trade liberalization is correlated with a decline in the relative price of goods in unskilled-intensive sectors. This implication, along with the other two mentioned in the last section, suggests that trade liberalization increases the nominal wage inequality within a region.

Finally, to estimate $\alpha^{n}_{(j,h)}$, it is assumed that it can be decomposed into an exporter effect, a sector specific effect and an importer specific taste for that sector as before. The exporter effect is then estimated from the sector-level non-homothetic gravity equation and the sum of the other two components is estimated from the sectoral expenditure shares.

Figure 2.7: Average Income and Income Elasticity of Production

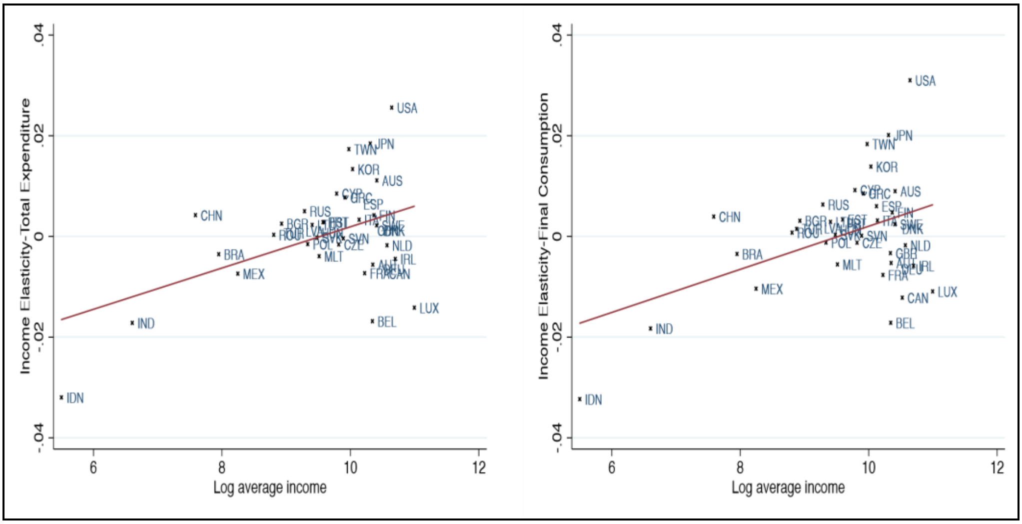
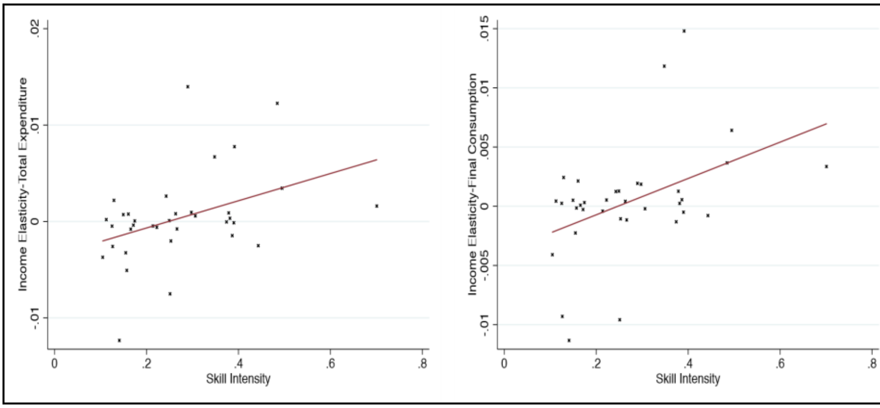


Figure 2.8: Skill Intensity and Sectoral Income Elasticity



2.4 Counterfactuals

Recall that the following equation can be used to compute the global welfare change of individual *z* between trade and a counterfactual scenario:

$$\underbrace{u_z^{tr \to cf}}_{\text{total effect}} = \underbrace{\left(\frac{E_{cf}^h}{E_{tr}^h}\right)}_{\text{agg. exp. eff.}} \underbrace{\left(\frac{\psi_z^{cf}}{\psi_z^{tr}}\right)}_{\text{ind. exp. eff.}} \underbrace{\left(\frac{w_z^{cf}}{w_z^{tr}}\right)}_{\text{income effect}}$$

The aggregate expenditure effect measures the reduction in the price index for the representative consumer in a region. The individual expenditure effect captures that, for individuals *z*, who is richer than the representative consumer, a decrease in the relative price of low-income elastic goods makes them better off. The change of the income effect depends on the sector that individual *z* works in. An increase in a sector's output price raises the relative nominal wage of the labor groups that disproportionately work in that sector in the initial trade equilibrium.

2.4.1 Five Percent Reduction in Trade Costs

First, a simultaneous 5% reduction in all bilateral trade costs, starting from the baseline parametrization, is considered. Since the focus is on the impact of trade liberalization on different groups of people, in particular, the poor versus the rich, the study investigates the difference in welfare change between the 10th percentile and the 90th percentile of the initial nominal wage distribution within each region that comes from each of the components in equation (14). Since the aggregate expenditure effect is the same for every individual within a region, it is differenced out. The following terms are defined as: **diff. exp. effect** = ind. exp. effect$_{z=10th}$- ind. exp. effect$_{z=90th}$; **diff. inc. effect** = income effect$_{z=10th}$ - income effect$_{z=90th}$; **diff. tot. effect** = total effect$_{z=10th}$ -total effect$_{z=90th}$.

Table 2.4: Distributional Effects through Income Channel

Active channel(s)	Income	Expenditure	Both
diff. exp. effect	0	[0.43,0.88]	[0.76,1.36]
diff. inc. effect	[-0.01,0.04]	0	[- 0.72, -0.04]
diff. tot. effect	[-0.01,0.04]	[0.43,0.88]	[0.24,1.29]

2.4.1.1 Income Channel

The study first looks at the distributional effects of trade liberalization through the income channel. The second column of **Table 2.4** reports the lower and upper bounds of **diff. exp. effect**, **diff. inc. effect**, **diff. tot. effect** across the 40 regions when only the income channel is active. The expenditure channel is shut down by imposing that $\beta_{(j,n)} = 0$ for all j, n. This brings the model back to a translog demand system, which is homothetic. Under these restrictions, the consumer price index for every individual within a region changes by the same amount,i.e. **diff. exp. effect**=0.

It is found that in Estonia, the 10th percentile suffers a decrease in the nominal wage relative to the 90th percentile of 0.01 percentage points. On the other hand, in Portugal, the 10th percentile enjoys an increase in the relative nominal wage by 0.04 percentage points. The change in the relative nominal wage for the rest of the regions lies in between.

Panel A of **Figure 2.9** plots **diff. inc. effect** against the log average income for each region based on a weighted least squares regression with weights equal to the output share of a region in the world economy. The correlation coefficient is -0.18. Panel B plots the skill abundance of a region against its log average income. The correlation coefficient is 0.77.[31] The income channel is found to benefit the poor more than the rich in low-income regions that are skill-scarce. These regions have a comparative advantage in unskilled-intensive sectors and a reduction in trade costs increases the relative nominal wage of the poor because they are less skilled and more likely to work in unskilled-intensive sectors. On the other hand, the income channel benefits the rich more than the poor in high-income regions that are skill-abundant. These regions have a comparative advantage in skill-intensive sectors and a reduction in trade costs increases the relative nominal wage of the rich because they are more skilled and more likely to work in skill-intensive sectors.

Figure 2.9: Distributional Effects through Income Channel

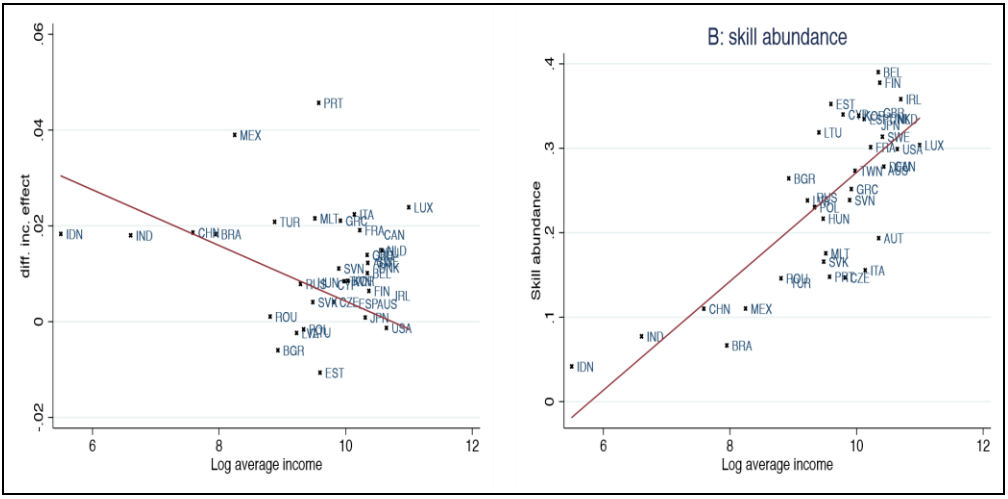


Table 2.4: Distributional Effects through Expenditure Channel

Active channel(s)	Income	Expenditure	Both
diff. exp. effect	0	[0.43,0.88]	[0.76,1.36]
diff. inc. effect	[-0.01,0.04]	0	[- 0.72, -0.04]
diff. tot. effect	[-0.01,0.04]	[0.43,0.88]	[0.24,1.29]

[31] A region's skill abundance, $H_n/(H_n + L_n)$, is measured as the share of workers with a completed tertiary degree (i.e. university graduates and post-graduates).

2.4.1.2 Expenditure Channel

Next, the study investigates the distributional effects of trade liberalization through the expenditure channel. The third column of **Table 2.4** reports the lower and upper bounds of **diff. exp. effect**, **diff. inc. effect**, **diff. tot. effect** across the 40 regions when only the expenditure channel is active. The income channel is shut down by imposing that T (λ, j) = 1 for all λ, j, that is, there is no comparative advantage of different labor types across sectors. Under these restrictions, the nominal wage of every individual within a region changes by the same amount, i.e. **diff. inc. effect**=0.

The expenditure channel is found to benefit the poor more than the rich in every region. More specifically, in Indonesia, the 10th percentile enjoys a reduction in the consumer price index that is 0.43 percentage points bigger than the 90th percentile. On the other hand, in Taiwan, the 10th percentile enjoys a reduction in the consumer price index that is 0.88 percentage points bigger than the 90th percentile. The poor's relative benefit from the expenditure channel for the rest of the regions lies in between.

Why does the expenditure channel imply a pro-poor bias in every region? The most direct effect of a reduction in trade costs is to decrease the homothetic price aggregator, which increases the inequality-adjusted real wage in every region *h*, and therefore decreases the expenditure shares on goods with $\beta_{(j,n)}$<0. This is an inward shift in the demand for low-income elastic goods which decreases their relative price. Since low-income consumers spend more on these goods, they benefit more from the expenditure channel.

Figure 2.10: Percentage Change Prices

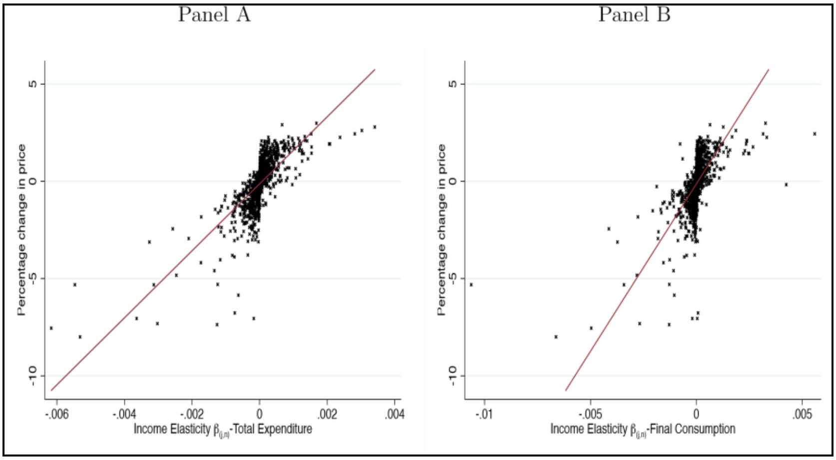
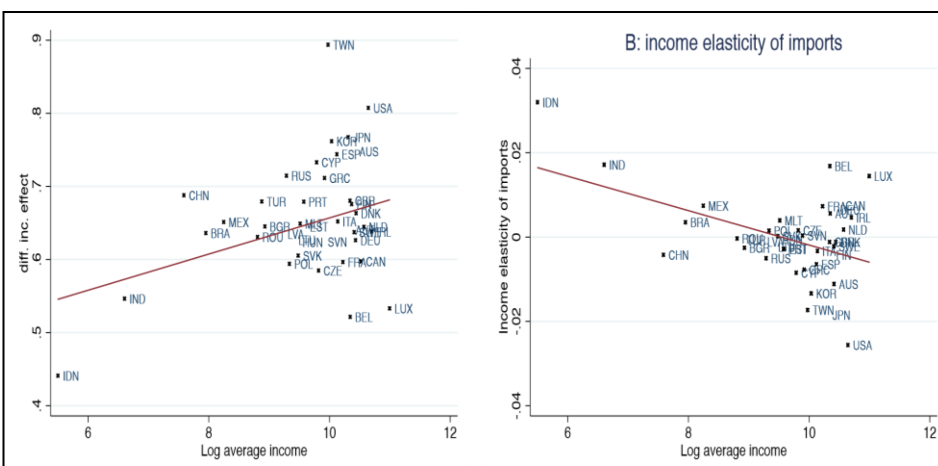


Figure 2.10 plots the percentage change in the price of each of the 1400 goods against its income elasticity. Panel A uses the income elasticity computed from total expenditure while Panel B restricts to final consumption. The correlation is strongly positive regardless of which estimate is used, that is, there is a decrease in the relative price of low-income elastic goods following trade liberalization.

Across regions, the expenditure channel is found to benefit the poor relative to the rich even more in high-income regions that import low-income elastic goods. Panel A of **Figure 2.11** plots **diff. exp. effect** against the log average income for each region based on a weighted least squares regression with weights equal to the output share of a region in the world economy. The correlation coefficient is 0.37. Panel B plots the income elasticity of imports of a region relative to its production against its log average income. The correlation coefficient is -0.30.Because high-income regions import low-income elastic goods, the decrease in the relative price of low-income elastic goods is magnified by the lower trade costs, which implies a bigger relative benefit from the expenditure channel for the poor.

Figure 2.11: Distributional Effects through Expenditure Channel



2.4.1.3 Both Channels

Finally, the study investigates the distributional effects of trade liberalization through both channels. It is found that as one moves up the income distribution, gains decline. More specifically, moving to the next decile reduces gains by about 0.1 percentage points. The third column of **Table 2.4** reports the lower and upper bounds of **diff. exp. effect**, **diff. inc. effect**, **diff. tot. effect** across the 40 regions when both the expenditure channel and the income channel are active. Since non-homothetic preferences allow people with different incomes to consume different bundles of goods, price changes resulting from trade liberalization can have a differential impact on an individual's consumer price index. A pro-poor bias from the expenditure channel is found in every region, i.e., **diff. exp. effect**>0. On average, the 10th percentile sees their consumer price index decrease by 1 percentage point more than the 90th percentile. In addition, since different labor groups sort into different sectors based on comparative advantage, price changes resulting from trade liberalization can have a differential impact on an individual's nominal wage. A pro-rich bias from the income channel is found in every region, i.e., **diff. inc. effect**<0. On average, the 10th percentile sees their nominal wage go down by 0.24 percentage points relative to the 90th percentile.[32] Since the expenditure effect dominates the income effect in magnitude, trade liberalization benefits the poor more than the rich in every region, i.e., **diff. tot. effect**>0. It is found that in Luxembourg, the 10th percentile enjoys an increase in the real wage relative to the 90th percentile of 0.24 percentage points. On the other hand, in Taiwan, the 10th percentile enjoys an increase in the relative real wage of 1.29 percentage points. The poor's relative benefit from both channels in terms of real wages for the rest of the regions lies in between. On average, the difference between the 10th and the 90th percentiles is about 0.8 percentage points.

Table 2.4: Distributional Effects through Both Channels

Active channel(s)	Income	Expenditure	Both
diff. exp. effect	0	[0.43,0.88]	[0.76,1.36]
diff. inc. effect	[-0.01,0.04]	0	[-0.72, -0.04]
diff. tot. effect	[-0.01,0.04]	[0.43,0.88]	[0.24,1.29]

More interestingly, the study finds that when both channels are active, the poor enjoy an even bigger relative reduction in consumer price indices in every region compared to the case where only the expenditure channel operates. More specifically, the range of **diff. exp. effect** across the 40 regions changes from [0.43,0.88] to [0.76,1.36]. In addition, the poor now suffer a relative decrease in nominal wages in every region. Note that the range of **diff. inc. effect** across

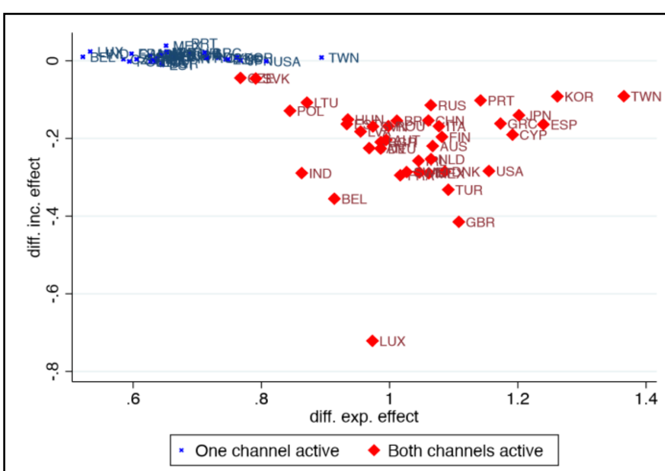
[32] A rise in nominal wage inequality is found in every region, which is qualitatively consistent with a wide range of empirical evidence. The impact of a 5% reduction in trade costs is a small change in relative wage, but a significant change in trade costs could have a big effect. It is also straightforward in the context of the model to introduce skill-biased technological change at the aggregate level. This study focuses on the impact of a change in trade costs holding technology fixed.

the 40 regions changes from [-0.01,0.04] to [-0.72, -0.04]. That is, the interaction of the two channels quantitatively changes the prediction of the differential impact of trade liberalization on the poor versus the rich through the expenditure channel and qualitatively through the income channel.[33]

To see the comparison visually, **Figure 2.12** plots (using blue x) **diff. inc. effect** when only the income channel is active against **diff. exp. effect** when only the expenditure channel is active, and then plots (using red diamond) **diff. inc. effect** against **diff. exp. effect** when both channels are active and interact. The interaction changes the estimates of both effects significantly. More specifically, each region moves to the right which implies that the poor's relative benefit from the expenditure channel is bigger. Also, each region moves downward and **diff. inc. effect**<0 for all of them, which implies that the rich benefit relative to the poor from the income channel in every region.

Why does the expenditure channel imply a bigger pro-poor bias and the income channel imply a pro-rich bias in every region? When both channels are active, lower trade costs reduce the relative demand for and the relative price of low-income elastic goods as discussed before. However, since the poor disproportionately produce unskilled - intensive goods which are low - income

Figure 2.12: Interaction of the Two Channels

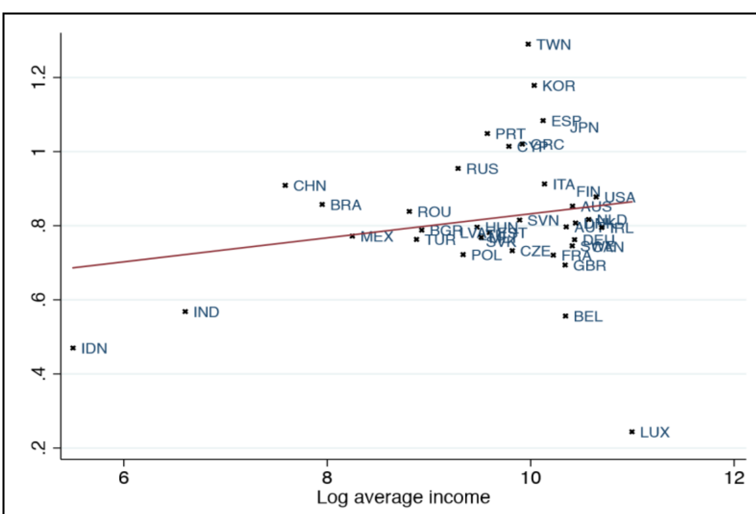


[33] It is assumed that all final good sectors are tradable and a decrease in trade costs in all sectors is considered to understand how the model works. Empirical findings suggest that non-tradable sectors typically have higher income elasticity. Consequently, allowing for non-tradability is expected to decrease the relative nominal wage of the poor and the relative price index for the poor. If the expenditure channel dominates the income channel in terms of magnitude as before, then the poor still benefit more from trade liberalization than the rich in every region.

elastic, their relative nominal wage goes down in every region. This implies that the income channel benefits the rich everywhere. This effect is absent when only the income channel is active because the income elasticity of every good is 0. On the other hand, as the nominal wage inequality goes up, the relative demand for and the relative price of low-income elastic goods fall even further, reducing the relative price index for the poor in every region. This implies that the expenditure channel benefits the poor even more compared to the case where only the expenditure channel is active. This effect is absent in that case because nominal wage inequality is constant.

How does the poor's relative benefit from the combined effect of trade liberalization vary across regions? **Figure 2.13** plots **diff. tot. effect** against the log average income for each region based on a weighted least squares regression with weights equal to the output share of a region in the world economy. The correlation coefficient is 0.19. Since the expenditure channel benefits more the poor individuals in rich regions and the rich individuals in poor regions, while the income channel benefits more the rich individuals in rich regions and the poor individuals in poor regions, allowing both channels to operate no longer makes income per capita a good predictor of the pro-poor bias of trade liberalization.[34]

Figure 2.13: Distributional Effects through Both Channels



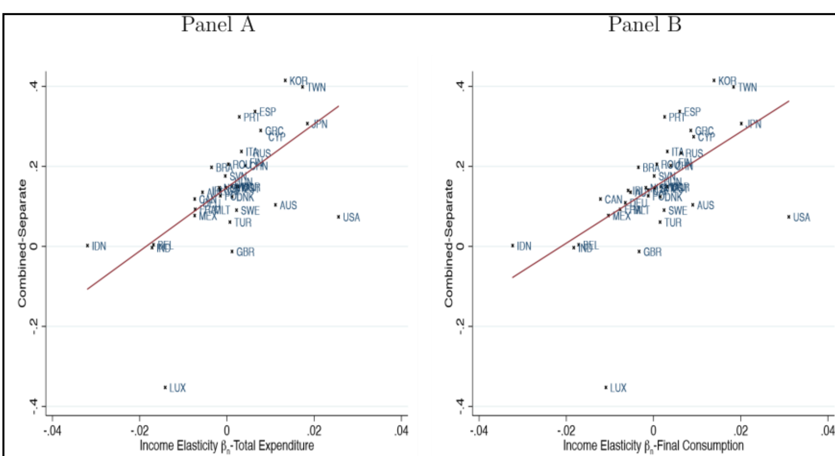
[34] since region characteristics are all correlated and pull in different directions, none in the data that is targeted has significant explanatory power for the variation in the model's predicted pro-poor bias of trade liberalization across regions.

2.4.1.4 Bias from Considering Two Channels Separately

Table 2.5 reports the bias from considering the two channels separately for each region. The second column adds up **diff. inc. effect** when only the income channel is active and **diff. exp. effect** when only the expenditure channel is active, which is then compared to **diff. tot. effect** when both channels are active as reported in the third column. It is found that estimating the two effects separately and adding them up generates a significant downward bias in the prediction for the poor's relative benefit from trade liberalization.

In particular, this underestimation is stronger in a country like Japan, which produces high- income elastic goods, compared to a country like Mexico, which produces low-income elastic goods. This pattern generalizes to the entire sample of 40 regions. **Figure 2.14** plots the difference in the poor's relative benefit from trade liberalization between estimating the two effects jointly and separately against the income elasticity of the region's production. Panel A uses the income elasticity computed from total expenditure while Panel B is restricted to final consumption. The correlation is strongly positive regardless of which estimate is used, that is, the interaction of the two channels benefits more the regions that produce high-income elastic goods.[35]

Figure 2.14: Underprediction of Pro-Poor Bias of Trade Liberalization



[35] Luxembourg is an outlier. It is one of the smallest sovereign states in Europe and has the world's highest GDP per capita. It also has the highest trade share in the sample of regions. Appendix B.4 shows that this correlation remains positive and significant after excluding Luxembourg.

Table 2.5: Bias from Considering Two Channels Separately

Region	Separate	Combined	Region	Separate	Combined
AUS	0.75	0.85	IRL	0.66	0.80
AUT	0.66	0.80	ITA	0.68	0.91
BEL	0.55	0.56	JPN	0.76	1.06
BGR	0.64	0.79	KOR	0.76	1.18
BRA	0.66	0.86	LTU	0.63	0.78
CAN	0.63	0.74	LUX	0.60	0.24
CHN	0.71	0.90	LVA	0.63	0.78
CYP	0.74	1.01	MEX	0.70	0.77
CZE	0.59	0.73	MLT	0.68	0.76
DEU	0.65	0.76	NLD	0.67	0.82
DNK	0.68	0.81	POL	0.60	0.72
ESP	0.75	1.08	PRT	0.73	1.05
EST	0.64	0.78	ROU	0.63	0.84
FIN	0.68	0.89	RUS	0.72	0.95
FRA	0.63	0.72	SVK	0.61	0.76
GBR	0.71	0.69	SVN	0.64	0.82
GRC	0.73	1.02	SWE	0.65	0.74
HUN	0.63	0.80	TUR	0.70	0.76
IDN	0.46	0.47	TWN	0.89	1.29
IND	0.57	0.57	USA	0.80	0.87

Intuitively, the interaction reallocates workers away from unskilled-intensive sectors that produce low-income elastic goods in every region because it decreases the relative price of low-income elastic goods. However, this is already the case in the regions that specialize in the production of high-income elastic goods without the interaction. Therefore, the interaction induces a smaller increase in worker reallocation away from unskilled-intensive sectors in these regions, which implies a bigger benefit for the poor who work in these sectors.

2.4.2 Rising Chinese Import Competition

Autor et al. (2013) analyze the effect of rising Chinese import competition between 1990 and 2007 on U.S. local labor markets, and they find that it causes higher unemployment, lower labor force participation, and reduced wages in local labor markets that serve import competing manufacturing industries.[36&37] They instrument for the growth in U.S. imports from China using Chinese import growth in other high-income markets to isolate the foreign supply-driven component of the changes, i.e., China's productivity growth and falling trade costs. In particular, for their base specifications, they focus on a single channel through which trade with China affects a region: greater import competition in the U.S. market. This ignores the effects of greater U.S. exports to China or greater import competition in the foreign markets that U.S. regions serve. Their main measure of local labor market exposure to import competition is the change in Chinese import exposure per worker in a region, where imports are apportioned to the region according to its share of national industry employment. They also control for the start-of-period manufacturing share within commuting zones so as to focus on variation in exposure to Chinese imports stemming from differences in industry mix within local manufacturing sectors.

Instead of using the variation across local labor markets, this study analyzes the aggregate effect of a $1K increase in U.S. manufacturing imports from China per worker.[38] At initial equilibrium, average per capita spending by the U.S. on Chinese manufacturing goods is:

$$\sum_{j\in M} S^{us}_{(j,chn)}\bar{w}^{us} = 0.0187 * 22.4128 = 0.42$$.[39]

[36] wage changes in autor et al. (2013) are in nominal and not real terms.

[37] it would be interesting and important to introduce unemployment or search into the framework. there would then be consequences about adjustment to trade shocks in the short- and medium-run.

[38] 1 unit in the framework is approximately $1000.

[39] sectors "agriculture" and "food, beverages and tobacco" are the food sectors; "mining" and from "textiles" to "manufacturing, nec" in the first column in table 2 and 3 are the manufacturing sectors. the remaining sectors are the service sectors.

To increase it by $1K is equivalent to an increase in the total expenditure share on these goods of 4.46%.[40]

The effects of greater U.S. exports to China or greater import competition in the foreign markets that the U.S. serves are shut down. To compute the reduction in trade costs in the manufacturing sectors that would lead to this increase in Chinese imports, the expenditure share equation is applied.[41] Plugging in the estimates of γ_j , it is found that $\log(d\tau) = -0.8$. Applying the expenditure share equation again, the impact of this reduction in trade costs on U.S. expenditure shares on domestic goods can be calculated. The U.S. production prices are solved again such that the U.S. market clearing conditions are still satisfied, taking into account the change in domestic demand.

It is found that production prices go down in all sectors in the U.S. as a result of rising Chinse import competition. They decrease in the manufacturing sectors because of the lower demand for the domestically produced goods, and in the non-manufacturing sectors because workers choose to leave manufacturing and work in other sectors in response to lower output prices and wages in manufacturing. This increases the labor supply in the non-manufacturing sectors, putting downward pressure on the output prices in these sectors. The individual expenditure effect implies a pro-poor bias of 0.45 percentage points, with individuals whose wages are at the 10th percentile of the initial distribution see a further 0.35 percentage points reduction in their consumer price indices compared to the representative consumer, and individual whose wages are at the 90th percentile see their consumer price indices decrease by 0.1 percentage points less than the representative consumer. This result comes from the fact that Chinese manufacturing goods are low-income elastic, and consequently, their lower prices benefit more the poor individuals who spend relatively more on these goods.[42] The income effect implies a pro-rich bias of 0.02 percentage points, while poor and unskilled workers see their nominal wages go down by 0.13%, and rich and skilled workers see their nominal wages go down by 0.11%. The reason that the former see a bigger decline in their nominal wages is because they are more likely to work in manufacturing sectors that are in direct competition with cheaper Chinese imports.

[40] note that this increase in spending on Chinese goods that author et al. (2013) consider is due to supply and trade-cost-driven changes in china's export performance, not changes in U.S. import demand as a result of higher income.

[41] Note that this increase in Chinese imports is attributed entirely to the reduction in trade costs for simplification. Suppose it is due to China's improved productivity instead, then its production prices would decrease. Both of these forces have the same effect on US consumer prices, each of which is the product of the production price and the trade cost. Note also that the change in these trade costs also affects y^{us} through its impact on $a(p^{us})$. It is ignored since this effect is negligibly small and does not change the result of the analysis.

[42] 11 out of China's 14 manufacturing sectors have $\beta_{(j,chn)}$<0.

The more pronounced decrease in the output prices in these sectors leads to the bigger decrease in their nominal wages. Combining all three effects, poor individuals gain 0.43 percentage points more compared to rich ones in terms of real wages as a result of the rising Chinese import competition. That is, the pro-rich bias of the income effect is more than offset by the pro-poor bias of the expenditure effect, which again underlines the importance of taking both channels into account in assessing the distributional effects of trade liberalization.

2.5 Conclusion

This chapter addresses the following question: what is the impact of trade liberalization on the distribution of real wages in a large cross-section of regions? The vast majority of the literature focuses on the effect of trade on the distribution of nominal wages. A small number of studies consider its differential impact on consumer price indices. There are only three case studies that have combined both channels to examine how real wages of different groups of people are affected in individual countries, Argentina, Mexico and India.

Sector-level trade and production data are used to estimate the parameters of the model in Chapter 1. As a result of a five percent reduction in all bilateral trade costs, the bigger decline in the poor's consumer price indices is found to more than compensate for their lower relative nominal wage. More specifically, in the average region, real wage of the bottom 10th percentile increases by 0.8 percentage points more than the top 10th percentile. It is also found that there is an important interaction between the two channels and, therefore, estimating the two effects separately and adding them up leads to a significant bias. These results highlight the importance of combining both channels in order to measure the distributional effects of trade accurately.

These findings have important policy implications for the distribution of winners and losers from trade reforms. There has been increasing public resistance to freer trade that originates from the belief that the most vulnerable group, i.e., the poor and unskilled, will be hurt the most. This chapter demonstrates that such a belief is misguided.

3. IMPORTED INPUTS AND WITHIN-SECTOR WAGE DISPERSION

3.1 Introduction

The traditional Heckscher-Ohlin model predicts that countries export goods that use intensively the factor they are most abundantly endowed with. According to the Stolper-Samuelson theorem, trade increases the relative return to unskilled labor in developing countries, decreasing wage inequality. However, that prediction is at odds with many empirical findings. Take China as an example, the overall wage inequality, measured as the difference between the 90th and the 10th percentile of the log wage distribution, has been going up consistently in the last two decades, as found in Han et al. (2012). This period of rapid wage inequality increase coincided with China's implementation of dramatic economic reforms and an open-door policy that promoted its trade with the rest of the world. So, two important questions arise: did trade liberalization contribute to China's rising wage inequality? If so, through which channels?

New theoretical developments have been made to provide insights into the effects of trade on wage inequality. Most prominently, Verhoogen (2008) proposes the quality-upgrading mechanism as an explanation. In his model with heterogeneous plants and quality differentiation, an exchange-rate devaluation leads more productive Southern plants to increase exports, upgrade quality, and raise wages relative to less productive ones, increasing within sector wage dispersion. This chapter proposes an alternative mechanism: the use of imported inputs. Intuitively, a firm with higher initial productivity is better at using higher quality foreign inputs. This justifies paying the fixed cost for a larger set of imported inputs when input tariff liberalization decreases their relative price. The firm becomes more import intensive, which enhances its productivity advantage. As a result, the firm hires higher quality workers, produces higher quality products and pays higher wages to its workers, increasing within-sector wage dispersion.

First, the ASIF (Annual Survey of Industrial Firms) from China's National Bureau of Statistics that report key operational data on Chinese manufacturing firms is used to document some stylized facts that are both new and interesting. The study finds that both the mean and the dispersion of the distribution of firm productivity, markup and size went up during a period when China reduced its tariffs on imported inputs. More importantly, these results still hold when the subset of firms that survived throughout the sample period, from 1998 to 2007, is considered. Therefore, openness to trade has fundamental effects on the underlying characteristics of firms. Most of recent models of firm heterogeneity assume that these characteristics are fixed and examine the impact of trade on aggregate variables, for example, the average productivity of firms in the economy as a result of change in the composition of surviving firms. On the contrary, this study investigates the differential impact of trade liberalization on heterogeneous firms allowing these characteristics to be endogenous.

Firm-level TFP is measured based on OLS, Olley and Pakes, Levinsohn and Petrin, and Ackerberg, Caves and Frazer to ensure that the estimate of firm productivity is as accurate as possible. For firm-level markup calculation, De Loecker and Warzynski (2012) is adopted, which is the best available method that can be used given the data limitations. Both a Cobb-Douglas gross output production function, and more generally, a trans log gross output production function, are considered, the latter of which matches the data much better. Finally, firm size is measured both in terms of output value and total employment as a robustness check. The empirical patterns are very similar when different approaches are used to measure these three-key firm-level variables.

Second, Chinese Customs Data on imports and exports are used, which provide detailed information on the universe of China's firm-level trade transactions for the years 2000 to 2006, to highlight firms' different responses to a dramatic decrease in import tariffs. These observations emphasize the large and growing importance of trade in intermediates, and provide some empirical evidence that supports the hypothesis that the differential change in the import intensity of firms with different productivity levels in response to input tariff liberalization explains the increase in both the average and the dispersion of firm-level variables that are observed in the data.

Finally, a partial equilibrium, heterogeneous firm model with endogenous imported inputs and labor quality choice that is consistent with these observations is developed. On the demand side, the "quality-Melitz" model in Kugler and Verhoogen (2012) is adopted, where higher price decreases demand but higher quality increases demand. On the supply side, firms differ from each other in the usual dimension of productivity, as in Melitz (2003). In the model, firms combine labor and intermediate inputs to produce physical quantity, in the spirit of Amiti et al. (2014). Output quality, on the other hand, is determined by labor and input qualities, and the advantage of imported inputs over domestic counterparts is augmented by a firm's own productivity. Since Amiti et al. (2014) focus on exchange rate pass-through, and assume that firms do not foresee fluctuations in exchange rates, they hold the set of imported inputs of each firm fixed. This study, on the other hand, investigates precisely how firms adjust the set of foreign varieties they import in response to input tariff liberalization and changes in firm-level variables that follow. Consequently, the model deviates from theirs in obvious ways, which is explained in more detail in the theory section.

Although the main focus of this chapter is to show that input tariff liberalization affects firms at different levels of productivity in a heterogeneous way, which drives their performance further apart, the results of the study have broader implications. Essentially, a framework is provided in which the differential impact of any element of globalization that leads to a decrease in the marginal cost of production on firm-level characteristics can be analyzed.

3.2 Related Literature

This chapter is related to several strands of literature. First, there have been studies on the labor market effects of international trade based on recent models of firm heterogeneity, and they ask how trade liberalization affects wages and wage inequality. For example, Amiti and Davis (2012) develop a model, which predicts that a fall in output tariffs lowers wages at import-competing firms but boosts wages at exporting firms, and that a fall in input tariffs raises wages at import-using firms relative to those that only source inputs locally. They find support for the model's predictions in Indonesian manufacturing census data for the period 1991-2000. Like this study, they take explicit account of firm-level heterogeneity and importance of trade in intermediates. Extending the heterogeneous firm model of trade and inequality from Helpman et al. (2010), Helpman et al. (2017) show that much of overall wage inequality arises within sector-occupations and for workers with similar observable characteristics, and wage dispersion between firms is related to firm employment size and trade participation. They again emphasize the importance of employing recent models of firm heterogeneity in analyzing the contribution of trade to the cross-section dispersion of firms. Frías et al. (2012), on the other hand, offer some empirical evidence that sorting on individual worker ability is not enough to explain the relationship between exporting and wages at the plant level.

They use a combination of employer-employee and plant-level data from Mexico, and show that approximately two-thirds of the higher level of wages in larger, more productive plants is explained by higher levels of wage premium, and that nearly all of the differential within-industry wage change is explained by changes in wage premium they use the late-1994 Mexican peso devaluation as a source of exogenous variation in the incentive to export, while this study uses import tariff reductions due to China’s accession to the WTO in December 2001 as the exogenous variation. On the contrary, Krishna et al. (2012) find an insignificant differential effect of trade openness on wages at exporting firms relative to domestic firms, using detailed information on worker and firm characteristics to control for compositional effects and allowing for the endogenous assignment of workers to firms. While these papers focus on the effects of trade liberalization on the labor market, this study looks at other firm-level characteristics, and ask how they are affected, and what are the resulting implications on wage inequality in China.

Second, the theoretical model borrows insights from a burgeoning research literature on firm import behavior, which has not been extensively studied before. Most importantly, evidence has been found in a wide range of countries that firm productivity rises when a firm imports new input varieties. For example, Kasahara and Rodrigue (2008) conclude that becoming an importer of foreign intermediates improves productivity using plant-level Chilean manufacturing panel data. At the same time, Halpern et al. (2015) find that importing all foreign varieties would increase firm productivity by 12 percent, and that during 1993-2002, one-third of the productivity growth in Hungary was due to imported inputs by estimating a model of importers in Hungarian micro data and conducting counterfactual policy analysis. Bas and Strauss-Kahn (2014), on the other hand, use a firm-level database of imports provided by French Customs for the 1995-2005 period, and find a significant impact of higher diversification and increased number of imported input varieties on firm-level TFP and export scope. They argue that importing more varieties of intermediate inputs increases firm productivity and thereby makes a firm more able to overcome the fixed export costs. The model in this chapter predicts that a firm with higher initial productivity has a stronger incentive to expand its set of imported varieties when it faces lower tariff rates, which then makes it even more productive, explaining the empirical patterns observed in the data.

Third, it is worth pointing out that these findings cannot be explained by any previous studies on heterogeneous firms. To start with, the workhorse model developed in Melitz (2003) assumes that the preferences of a representative consumer are given by a C.E.S. utility function over a continuum of goods, so each firm chooses the same profit maximizing markup, which is constant. After paying fixed entry costs, firms draw their initial productivity parameter, which does not change over time. As a result, the mean and the dispersion of the productivity distribution of a balanced panel of firms remain the same, which is not what is observed in the data. Gains from trade in his model come from expansion in product varieties, and more importantly, the self-selection of more efficient firms into exporting. Relaxing the C.E.S. assumption, Arkolakis et al. (2015) study how variable markups affect the gains from trade liberalization under monopolistic competition, and they show that the welfare effect of a small trade shockis given by $dlnW = -(1-\eta)\frac{dln\lambda}{\epsilon}$, where $\lambda$is the share of expenditure on domestic goods, $\epsilon$is an elasticity of imports with respect to variable trade costs, and $\eta$is a structural parameter that depends, among other things, on the elasticity of markups with respect to firm production. Although they consider variable markups like this study, they assume that firm-level productivity is the realization of a random variable drawn independently across firms from a distribution, which is unbounded Pareto, and it is fixed over time. Instead of a counterfactual analysis that focuses on the welfare effect of a particular shock, Feenstra and Weinstein (2010) use a translog demand system to measure the effects of new varieties and variable markups on the change in the U.S. consumer price index between 1992 and 2005. That is, they use observed trade data to infer changes in particular components of the U.S. price index. Their results highlight the importance of taking into account the implications of pro-competitive effect of trade. However, they ignore the impact of trade on productivity since that is not the main focus of their paper. On the other hand, Feenstra (2014) shows that self-selection of more efficient firms into exporting is the only source of welfare gains when using a Pareto distribution for productivity with a support that is unbounded above. He restores a role for product variety and pro-competitive gains from trade, but still assumes that firms receive a random draw of productivity from a Pareto distribution, which does not change. Finally, borrowing insights from Melitz (2003) that trade openness increases volatility by making the economy more granular since only the largest and most productive firms export, while smaller firms shrink or disappear, Di Giovanni and Levchenko (2013) show that when the distribution of firm sizes follows a power law with an exponent close to -1, the idiosyncratic shocks to large firms have an impact on aggregate output volatility. In their model, these firm-level idiosyncratic shocks may explain the observed increase in dispersion of firm size distribution, but they do not provide a micro foundation to explain why both the mean and the standard deviation of the distribution go up in a systematic way since they assume i.i.d. transitory shock. Essentially, these theoretical papers consider the effect of a change in the exogenous distribution of firm productivity, while this study takes firm productivity as an endogenous variable. Therefore, it is able to add something new and interesting to the conversation about the impact of trade based on recent models of firm heterogeneity.

3.3 Data

The first dataset, Chinese Customs Data on imports and exports, provides detailed information on the universe of China's firm-level trade transactions for the years 2000 to 2006. In addition to firm identifiers, this dataset includes information on many important transaction characteristics, including customs regime (e.g. processing trade or ordinary trade), 8-digit HS product code, transaction value, quantity, and source or destination country. Using firm identifiers provided in the dataset, key variables that describe firm-level imports and exports are constructed. **Figure 3.1** illustrates the customs declaration form that a firm has to fill out if it intends to import from or export to foreign countries.

The second key dataset is from China's National Bureau of Statistics, which conducts firm-level surveys on manufacturing enterprises. These data collected from Chinese firms include key operational information, such as firm employment, ownership type (e.g. state-owned enterprise, foreign invested firm, or private firm), sales value, R&D expenditure and industry. Merging the firm-level data with the transaction-level data is challenging because firm identifiers used in the two datasets are different. Nevertheless, since both datasets include extensively detailed firm contact information (e.g. company name, telephone number, zip code, contact person), they are merged using zip codes and the last seven digits of a firm's phone number, following Yu (2015). In this way, firm-level observations that combine information on the trade with the operational activities of Chinese firms are generated.

Figure 3.1: Customs Declaration Form

Table 3.1 compares some of the main characteristics of merged and unmerged firms, and they look very similar on average in terms of employment, sales, value added per worker and TFP, mitigating the concern about sample selection bias.

Table 3.1: Comparison of Merged with Unmerged Firms in the Data

	Merged Firms	Unmerged Firms
Log Employment	5.37 [1.13]	5.27 [1.17]
Log Sales	10.6 [1.30]	10.33 [1.31]
Value Added per Worker	87.32 [203.32]	71.58 [147.69]
TFP (Olley Pakes)	4.22 [1.15]	4.12 [1.12]

3.4 Stylized Facts

To motivate the theoretical model, some stylized facts about the change in firm-level productivity, markup and size during a period of large scale trade liberalization are presented. The study focuses on a balanced panel, that is, the set of manufacturing firms that survived the entire sample period, from 2000 to 2006, since the within-firm change due to open trade is the main interest of this chapter. Unlike most previous literature that only looks at how these variables change on average, the change in dispersion is also considered, and it is demonstrated that the sample mean is no longer sufficient to explain the impact of trade liberalization on firm performance and the resulted wage inequality within a country. Both the mean and the standard deviation of these three variables are found to go up during this period.

3.4.1 Productivity

Firm-level TFP is measured based on a few different approaches. Besides simple OLS, Olley and Pakes (OP), a method for robust estimation of the production function allowing for endogeneity of the inputs, selection and unobserved permanent differences across firms, is used. Essentially, they use investment to proxy for firm productivity shock in the first stage, and then use semi-parametric selection correction to correct for endogenous exit. The traditional OP procedure is extended by including an exporter dummy, following Amiti and Konings (2007). Second, Levinsohn and Petrin (LP) is applied, which instead of investment, uses material expenditures as proxy for productivity shock, since investment is zero for many firms. Finally, Ackerberg, Caves and Frazer, a GMM procedure using orthogonality of lagged labor and productivity shock, is adopted. They argue that labor and investment in OP, or labor and material expenditures in LP are likely to be collinear. All of these approaches generate very similar measures of TFP, so only the results based on OP and LP are reported. However, it is worth pointing out that these TFP measures are still subject to the usual criticism, that is, they are a residual that lumps together many things: technical efficiency, markups, input and output quality and measurement error. These issues are not addressed directly here since that is not the focus of this chapter. With better data, on the other hand, a more robust measure of firm-level TFP is possible.[43] Note that there is an increase in both the mean and the dispersion of firm-level productivity.

Table 3.2: Productivity, 1999-2007 Pooled

Specification	Average TFP (Standard Deviation)	Median TFP
LP	3.68 (1.09)	3.7
OP	4.61 (1.02)	4.59

Table 3.3: Productivity, 1999

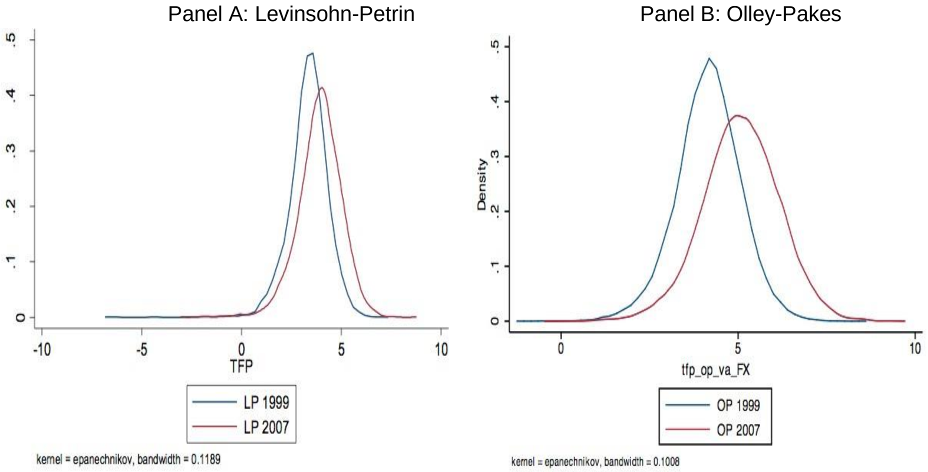
Specification	Average TFP (Standard Deviation)	Median TFP
LP	3.32 (1.03)	3.37
OP	4.16 (0.92)	4.18

Table 3.4: Productivity, 2007

Specification	Average TFP (Standard Deviation)	Median TFP
LP	4.00 (1.18)	4.03
OP	5.08 (1.09)	5.09

[43] See De Loecker (2013).

Figure 3.2: Balanced Panel TFP Estimation



3.4.2 Markup

To estimate firm-level markups, the method in De Loecker and Warzynski (2012) is adopted. Their approach relies on cost-minimizing producers and the existence of at least one variable input of production. This empirical framework relies on the estimation of a production function and provides estimates of plant-level markups without specifying how firms compete in the product market. There are several advantages in using their method. First, their markup estimates are obtained using standard production data where output, total expenditures on variable inputs, and revenue at the plant level are observed. Second, and more importantly, a few key assumptions maintained in previous empirical work are relaxed. For example, constant returns to scale does not need to be imposed, and the user cost of capital does not need to be observed or measured.

Empirically, two variations of the production function, a Cobb-Douglas gross output production function and a translog gross output production function, are considered. An estimate of markup for each firm i at each point in time t is obtained while allowing for considerable flexibility in the production function, consumer demand, and competition. The estimation procedure is essentially the same when a Cobb-Douglas gross output production function is considered. Higher-order and interaction terms are simply dropped. Labor is assumed to be either a fully flexible input, that is, a control variable correlated with contemporaneous productivity shock, where lagged labor is used as an instrument, or a predetermined variable, that is, a state variable, independent of contemporaneous shock, when hiring and firing costs are taken into account, and itself is used as an instrument.

Table 3.5: Markup, 1999-2007 Pooled

Specification	Average Markup (Standard Deviation)	Median Markup
CD (L as control variable)	1.19 (0.27)	1.24
CD (L as state variable)	1.25 (0.23)	1.27
TL (L as control variable)	1.21 (0.13)	1.18

Table 3.6: Markup, 1999

Specification	Average Markup (Standard Deviation)	Median Markup
CD (L as control variable)	1.16 (0.26)	1.20
CD (L as state variable)	1.22 (0.22)	1.23
TL (L as control variable)	1.13 (0.09)	1.11

Table 3.7: Markup, 2007

Specification	Average Markup (Standard Deviation)	Median Markup
CD (L as control variable)	1.25 (0.30)	1.29
CD (L as state variable)	1.31 (0.26)	1.32
TL (L as control variable)	1.30 (0.16)	1.28

Different specifications generate very similar estimates of markups. When markups are compared across the years, especially at the beginning and at the end of the sample period, it becomes clear that there is a substantial increase in both the mean and the dispersion of the distribution of markups, most evidently in the case of a translog gross value production function.

Figure 3.3: Balanced Panel Markup Estimation I

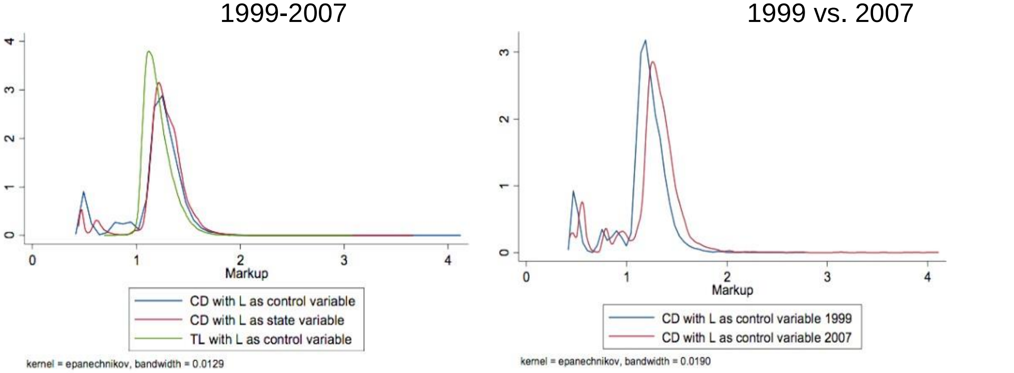
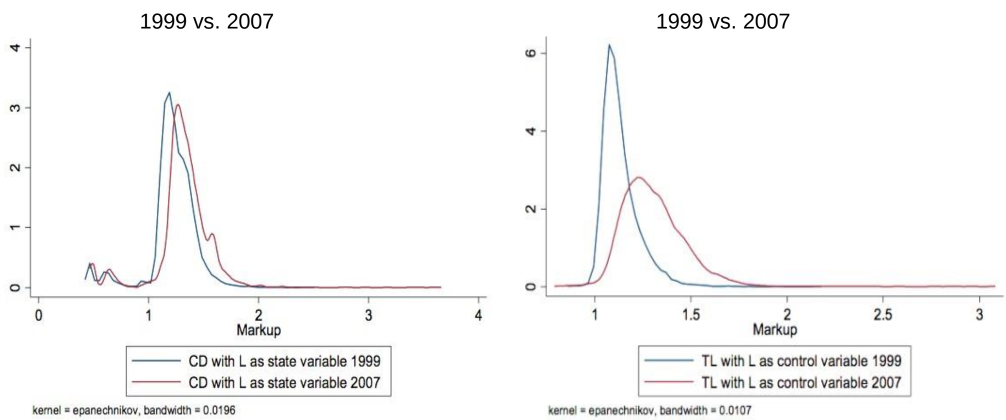


Figure 3.4: Balanced Panel Markup Estimation II



3.4.3 Firm Size

Firm size is measured in terms of log output value, both in nominal terms and deflated by 4-digit industry output deflator, and in terms of log employment. Its change follows the same pattern as firm productivity and markups, that is, both the mean and the dispersion of its distribution go up.

Table 3.8: Firm Size, 1999-2007 Pooled

Specification	Mean (Standard Deviation)	Median
Log (nominal output value)	10.62 (1.35)	10.45
Log (deflated output value)	10.64 (1.34)	10.47
Log (employment)	5.41 (1.12)	5.32

Table 3.9: Firm Size, 1999

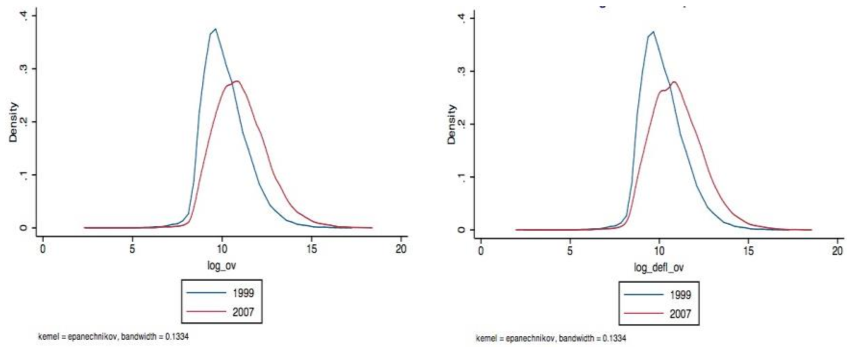
Specification	Mean (Standard Deviation)	Median
Log (nominal output value)	10.18 (1.22)	10
Log (deflated output value)	10.21 (1.22)	10.03
Log (employment)	5.36 (1.13)	5.26

Table 3.10: Firm Size, 2007

Specification	Mean (Standard Deviation)	Median
Log (nominal output value)	11.04 (1.49)	10.91
Log (deflated output value)	11 (1.48)	10.87
Log (employment)	5.4 (1.15)	5.3

Figure 3.5: Balanced Panel Firm Size Estimation

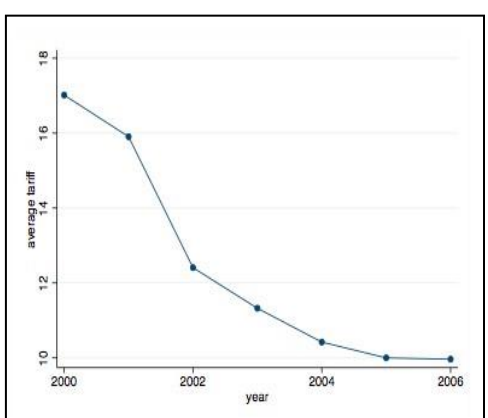
Log nominal output value Log deflated output value



3.5 Tariff Reductions and Imported Inputs

Since China joined the WTO in December 2001, it lowered its average tariff significantly, from 16% to a little above 12% within one year from 2001 to 2002, and the average tariff kept declining steadily over the entire sample period. The last year in the sample, 2006, saw an average tariff rate of only about 10%. It is indeed one of the most dramatic trade liberalization episodes in China's history. As a commitment to its WTO accession, China also agreed to eliminate all quotas, licenses, tendering requirements and other non-tariff barriers to imports of manufactured goods by 2005.

Figure 3.6: Average Tariff at HS-8 Level



Source: Trade Analysis and Information System (TRAINS) and WTO tariff database

To motivate the theoretical model, the study looks at how heterogeneous firms at different productivity levels adjust their set of imported varieties during this period of dramatic input tariff liberalization. It is found in the data that firms that belong to a higher quartile of the productivity distribution expanded the number of foreign varieties that they imported by more. This observation leads to an important feature of the model, which is explained in the theory section.

It is also found in the data that firms on average increased the number of their imported products and source countries significantly between 2001 and 2002, when they experienced the biggest tariff reductions. They kept expanding their imported varieties (product-country pairs) until 2004, which then tapered off. Firms typically import a large number of products from a number of countries, and therefore, it is assumed that firms can import a continuum of foreign varieties if they find it beneficial.

Table 3.11: Firm Productivity and Newly Imported Varieties

2001		***2002***	
Productivity Quartile	**Mean of Newly Imported Varieties**	**Productivity Quartile**	**Mean of Newly Imported Varieties**
Q1	3.95	Q1	5.35
Q2	4.21	Q2	5.42
Q3	4.48	Q3	6.75
Q4	8.17	Q4	10.72
2003		***2004***	
Productivity Quartile	**Mean of Newly Imported Varieties**	**Productivity Quartile**	**Mean of Newly Imported Varieties**
Q1	5.21	Q1	4.77
Q2	6.38	Q2	5.84
Q3	7.78	Q3	7.49
Q4	13	Q4	12.79
2005		***2006***	
Productivity Quartile	**Mean of Newly Imported Varieties**	**Productivity Quartile**	**Mean of Newly Imported Varieties**
Q1	4.27	Q1	3.62
Q2	5.61	Q2	5.14
Q3	7.08	Q3	6.81
Q4	12.24	Q4	11.21

Table 3.12: Number of Imported Products, Source Countries and Varieties

2001				***2002***			
	Products	**Source Countries**	**Varieties**		**Products**	**Source Countries**	**Varieties**
Mean	158	16	278	Mean	181	18	331
Median	92	14	127	Median	105	15	145
2003				***2004***			
	Products	**Source Countries**	**Varieties**		**Products**	**Source Countries**	**Varieties**
Mean	183	19	348	Mean	188	19	370
Median	108	15	153	Median	108	15	155
2005				***2006***			
	Products	**Source Countries**	**Varieties**		**Products**	**Source Countries**	**Varieties**
Mean	179	19	363	Mean	157	19	327
Median	102	15	146	Median	90	15	137

3.6 Model

This section presents a partial equilibrium, heterogeneous firm model with endogenous imported input and labor quality choice to account for the aforementioned empirical findings. On the demand side, the "quality-Melitz" model in Kugler and Verhoogen (2012) is adopted, where higher price decreases demand but higher quality increases demand. On the supply side, firms differ from each other in the usual dimension of productivity, as in Melitz (2003). In themodel, firms combine labor and intermediate inputs to produce physical quantity, in the spirit of Amiti et al. (2014). Output quality, on the other hand, is determined by labor and input quality, and the advantage of imported inputs over domestic counterparts is augmented by a firm's own productivity.

3.6.1 Demand

Similar to Kugler and Verhoogen (2012), a representative consumer has a constant elasticity-of-substitution (CES) utility function:

$$U = \left[\int_{i=1}^{I} (q_i y_i)^{\frac{\sigma-1}{\sigma}} di\right]^{\frac{\sigma}{\sigma-1}}$$

where I denotes the set of all differentiated varieties available; i indexes a particular variety; σ>1 is the constant elasticity of substitution between different varieties; y_i is the quantity of variety i consumed; q_i is the output quality of variety i, chosen by the firm producing variety i and it is assumed to be observable to all.

Consumer optimization yields the following demand function for variety i:

$$y_i = YP^{\sigma} q_i^{\sigma-1} p_i^{-\sigma}$$

where p_i is the price of variety i charged by the firm; $Y = U$ is the quality-adjusted aggregate consumption in the economy; P is the quality-adjusted ideal price index. This demand function is increasing in the quality and decreasing in the price.

3.6.2 Production

There is a continuum of firms of measure $|I|$, each producing one differentiated variety. Without any ambiguity, i is used to index the firm producing variety i. Firms differ from each other in their productivity drawn from a known distribution upon entering the market and are thereafter fixed, as in Melitz (2003).[44]

First, consider a particular firm i. Its production can be summarized by two production functions - one characterizing the production of physical quantity, y_i, and the other characterizing the production of output quality, q_i. The production of physical quantity is summarized by a Cobb-Douglas production function:

$$y_i = \varphi_i L_i^{1-\phi} X_i^{\phi}$$

$$X_i = exp\left\{\int_0^1 \gamma_j \log(X_{ij})\, dj\right\}$$

$$X_{ij} = Z_{ij} + \varphi_i^b a_j M_{ij}$$

L_i is the amount of labor used. $0 < 1-\phi < 1$ is the labor share of variable costs. X_i is the intermediate input aggregated from a continuum of inputs of measure 1, indexed by j. $\gamma_j > 0$ is the importance of input j among all intermediate inputs, with $\int_0^1 \gamma_j dj = 1$.

[44] Here, the support of the distribution is assumed to be bounded below by 1. This assumption is made mainly to eliminate scenarios in which low productivity firms make high quality foreign inputs less efficient than low quality domestic inputs.

X_{ij} is the amount of input *j* used. For each input *j*, there are both domestic and foreign varieties denoted by Z_{ij} and M_{ij} respectively, which are perfect substitutes. The foreign variety has a natural advantage, $a_j > 1$, over its domestic counterpart. However, the actual advantage, $\varphi_i^b a_j$, is the natural advantage augmented by a firm's productivity, implying that more productive firms are able to use the same foreign input more efficiently than less productive ones. $b > 0$, is a parameter that governs the differential efficiency of foreign input use between firms at different levels of productivity - the larger *b* is, the greater the differential efficiency.

The production of output quality is summarized by a constant-returns-to-scale supermodular function in labor quality and intermediate input quality:

$$q_i = \left[(1-\phi)\, c^{\theta} + \phi \int_0^1 \gamma_j b_j^{\theta} dj\right]^{\frac{1}{\theta}}$$

$$b_j = \begin{cases} 1 & j \in J_i^Z \\ \varphi_i^b a_j & j \in J_i^M \end{cases}$$

c is the labor quality chosen by the firm;[45] b_j is the quality of intermediate input *j*; J_i^Z represents the set of inputs for which domestic varieties are used, and $J_i^M = [0,1] \setminus J_i^Z$ represents the set of inputs for which foreign varieties are imported; $\theta < 0$ captures the constant degree of complementarity between labor quality and intermediate input quality. A more negative θ represents a stronger complementarity. With this specification, firms using higher quality foreign inputs also have a greater incentive to use higher quality labor to complement them.

It is assumed that there is only domestic labor market, given the low international mobility of labor relative to capital and intermediate inputs. Workers, *l*, are ex-ante homogeneous with wages normalized to 1. There exists a sector that transforms homogeneous labor into different quality, with the production function: $F(l,c) = \frac{l}{c}$. This implies that the marginal cost of producing one unit of labor with quality *c* is $c \cdot 1 = c$. Labor market is assumed to be perfectly competitive, hence the price of labor of quality *c* is $p_L(c) = c$.

For intermediate input *j*, there are domestic market and foreign market. Firms are price takers in both. The equilibrium prices of domestic variety and foreign variety are p_j^Z and p_j^M respectively. [46] However, on top of the price, p_j^M,

[45] Labor quality, *c*, is a continuous variable with positive support. It is perfectly observable to firms, so there are no asymmetric information problems.

[46] Both are expressed in terms of a home currency. Exchange rates are not the focus of this chapter.

there are variable trade costs, $\tau_j \geq 1$, in the form of iceberg costs. In other words, for a firm to acquire one unit of foreign variety of input *j*, it has to pay for τ_j units at the costs of $\tau_j \, p_j^M$.

It is assumed that there are no fixed costs of importing at each input level.[47] However, each firm has to pay fixed import costs, f_M, if it switches from not importing at all to importing some inputs. There are also fixed costs of production, *f*, in each period.

3.6.3 Equilibrium

In order to solve the firm's profit maximization problem, the strategy in Amiti et al. (2014) is followed. The problem is broken down into two stages. In the first stage, the set of imported inputs, I_i^M, is held fixed and the optimization problem is solved conditional on I_i^M. In the second stage, I_i^M is allowed to vary so that the optimal set of imported inputs, I_i^{M*}, can be pinned down.

3.6.3.1 Stage 1: Profit Maximization Conditional on a Fixed Set of Imported Inputs

In this stage, the set of imported inputs is fixed.[48] Firm optimization yields first-order conditions that can be used to solve for the optimal labor quality, output quality, output quantity and profits, conditional on I_i^M.

They imply that, conditional on the same set of imported inputs, firms with higher productivity can make more out of foreign inputs and thus hire higher quality labor to complement them, ultimately producing higher quality outputs. Conditional on the same productivity, firms that import a larger set of inputs also hire higher quality labor due to the increase in the quality of intermediate inputs, and also produce higher quality outputs. As a result, these firms pay higher wages to its workers.

[47] This is mainly to avoid the problem of multiple equilibria. Amiti et al. (2014) have fixed costs of importing at each input level. But they fix the set of imported inputs before the choice of output in equilibrium, because the exchange rate shocks in their paper are assumed to be unforeseen. This chapter, however, wishes to allow both output and the set of imported inputs to respond to a change in the variable trade costs. The addition of fixed costs of importing at each input level will thus introduce multiple equilibria.

[48] Attention is restricted to firms that import. The determination of the cutoff below which firms never import is discussed in the next section, by comparing the firm's profits given its optimal set of imported inputs with those when it does not import any inputs.

3.6.3.2 Stage 2: Determination of the Optimal Set of Imported Inputs

In this stage, a recursive algorithm is formulated that pins down the optimal set of imported inputs. Before that, first consider a firm with its current set of imported inputs, J_i^M, contemplating on whether to import foreign variety for input *j*. In other words, input *j* is moved from the set J_i^Z to J_i^M. After the endogenous adjustment of labor quality, output quality and quantity, the resulting change in profits can be specified. Under the assumptions on the parameters, its sign is given by:

$$\text{sign}\left(d\Pi_i\right) = \text{sign}\left(\frac{1}{\theta}q_i^{-\theta}\left(\varphi_i^{b\theta}a_j^{\theta} - 1\right) + \log\frac{\varphi_i^b a_j p_j^Z}{\tau_j p_j^M}\right)$$

Note that since there are nofixed costs of importing at each input level, its sign is independent of the scale of production, thus avoiding the problem of multiple equilibria. The first termis always positive, representing the benefits of importing an extra input *j* on output quality, and hence, total revenue. These benefits are increasing in output quality, q_i, due to complementarity between quality of newly imported input *j* and quality of existing imported inputs in J_i^M. This implies that there is no crowding out effect - importing more inputs does not make importing other inputs less desirable. In fact, there is crowding in - importing more inputs increases the benefits of importing an extra input, thus increasing the likelihood of importing that input. These benefits are also increasing in firm productivity because more productive firms can make more out of the same imported input *j*.[49] The second term can be either positive or negative, depending on the advantage-and-trade-cost-adjusted relative price. If foreign variety is relatively cheaper than domestic variety, then conditional on already importing some inputs, that is, the firm has already paid the fixed costs of importing at the first unit, it is always willing to import such input *j* because importing is both quality-enhancing and cost-saving.

Next, the optimal set of imported inputs is characterized. Unlike the framework in Amiti et al. (2014), which has a cutoff implicitly defined because the marginal cost of importing is fixed and the marginal benefit of importing is monotonically decreasing, the model does not have a sorting of the inputs nor an implicitly defined cutoff. Instead, the optimal set is defined recursively and sequentially using an algorithm. The optimality of the defined set and some of its other desirable properties are proved in the next subsection. For expository

[49] Here, the study conditions on fixed output quality, q_i. This result holds more strongly if q_i is an increasing function in firm productivity.

simplicity, define: as the conditional optimal output quality for firm *i* that imports the set of inputs, S,and uses domestic varieties for the complementary set.

An immediate lemma is:

Lemma 1 For any two sets, $S_1 \subset S_2 \subseteq [0,1]$, and some firm *i* with productivity φ_i, $q_i(S_1) < q_i(S_2)$. For any two firms *i* and i' with productivity $\varphi_i < \varphi_{i'}$ and any set $S \subseteq [0,1]$, $q_i(S) < q_{i'}(S)$. Combining the two results leads to $q_i(S_1) < q_{i'}(S_1) < q_{i'}(S_2)$.

The proof is trivial once it is noted that $\varphi_i^b a_j > 1$.

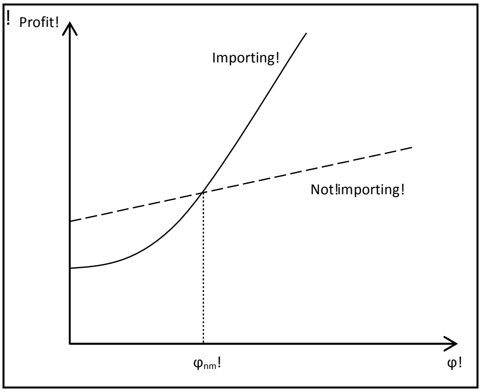
On the other hand, the optimal set of imported inputs, conditional on having paid f_M, can be determined recursively.

3.6.3.3 Determination of No-import Cutoff

Due to the existence of the fixed costs of importing at the first unit, not every firm engages in importing. Firms below a productivity threshold do not import any input while firms above that threshold do. This threshold is determined by comparing the profits if the firm imports with those if it does not. The marginal firm is indifferent between importing and not.

Even though profits of both importing and not importing are increasing in firm productivity, the former increases much faster than the latter, but the former starts at a lower value due to the existence of f_M. Hence, as illustrated in the figure below, the two profit lines have one intersection, after which importing inputs generates higher profits than not importing. This pins down the no-import cutoff.

Figure 3.7: No-import Cutoff



3.6.4 Model Implications

In this section, some of the properties implied by the model that guide the empirical investigations are outlined. Some of these properties come naturally out of the model while others require additional assumptions on the parameters of the model.

3.6.4.1 No-import Cutoff

First, how the set of firms that engage in importing respond to trade liberalization in the form of import tariff reductions is examined. Clearly the profit schedule of not importing does not change with import tariff reductions. The profit schedule of importing does, but this change may or may not affect the no-import cutoff, depending on the nature of import tariff reductions. An immediate result is that if there is a uniform decrease in import tariffs, the no-import cutoff decreases. More generally, if there is a decrease in tariff on some input in the optimal set of imported inputs of the original marginal firm, the cutoff decreases. This result is consistent with empirical findings that following trade liberalization, previously non-importing firms in the balanced panel start to import higher quality foreign inputs.

3.6.4.2 Optimal Set of Imported Inputs

Since the optimal set of imported inputs is at the center of the model, determining equilibrium labor quality, output quality and quantity, the properties of this set are investigated.

Proposition 2: All other things being equal, a more productive firm imports a weakly larger set of foreign inputs.

Proposition 3: All other things being equal, a reduction in variable trade costs for input *j* increases the likelihood of importing that input for a firm that previously does not import it. Furthermore, it also increases the likelihood of importing other inputs that are not imported before by the firm, if input *j* is now imported.

Proposition 3 is quite intuitive because a reduction in variable trade costs decreases the costs of importing *j* while keeping benefits unchanged. Hence the firm is more likely to import *j*. Conditional on *j* being imported after the reduction in trade costs, the set of imported inputs expands and the output quality increases, further increasing the benefits of importing other inputs due to the crowding in effect. Hence, the likelihood of the firm importing other inputs increases.

Proposition 3 can be generalized to reductions in multiple or all variable trade costs. The increase in the likelihood is much bigger if the variable trade costs of many inputs that are previously not imported by the firm decrease at the same time.

3.6.4.3 Labor Quality, Output Quality, and Wages

Recall that for firms above the no-import threshold, the optimal labor quality and output quality are given by:

$$c = q_i = \left[\int_{J_i^{Z*}} \gamma_j dj + \int_{J_i^{M*}} \gamma_j \varphi_i^{b\theta} a_j^{\theta} dj \right]^{\frac{1}{\theta}}$$

where J_i^{Z*} is the equilibrium set of domestic inputs.

By proposition 2, a more productive firm imports a weakly larger set of foreign inputs. Hence, it is obvious from the above expression that this more productive firm uses strictly higher quality labor and produces strictly higher quality output. Since equilibrium labor quality is higher for a more productive firm, it also pays higher wages because $p_L(c) = c$.

Trade liberalization in the form of tariff reductions increases the set of imported inputs for some, if not all, firms, by proposition 3. These firms switch to higher quality foreign inputs, and hire higher quality labor to complement them. As a result, they produce higher quality output and pay higher wages.

Suppose the tariff reductions induce a decrease in the no-import cutoff as in the first case in proposition 1. Then for those firms that switch from not importing at all to importing some foreign inputs, their labor quality and output quality increase from

$$c = q_i = \left[\int_0^1 \gamma_j dj \right]^{\frac{1}{\theta}} = 1 \text{ to } \left[\int_{J_i^{Z*}} \gamma_j dj + \int_{J_i^{M*}} \gamma_j \varphi_i^{b\theta} a_j^{\theta} dj \right]^{\frac{1}{\theta}} > 1.$$

The more productive the firm is, the bigger the increase, because φ_i and J_i^{M*} are both larger by proposition 2. As a result, they also pay higher wages after trade liberalization.

For those firms that never import, there is no change in the labor quality, output quality and wages before and after trade liberalization. They are consistently using the low skill labor, $c = 1$, producing low quality output, $q_i = 1$, and paying low wages, $p_L(1) = 1$.

3.6.4.4 Firm Profits

In terms of firm profits, there is a similar set of predictions. Conditional on the same set of imported inputs, a more productive firm has higher profits because of its higher φ_i and higher q_i. By proposition 2, it also imports a weakly larger set of inputs. It chooses to do so because by importing more, its profits increase. Therefore, it has been shown that a more productive firm enjoys higher profits. Trade liberalization in the form of input tariff reductions generates higher profits for any firms, provided that they are importing inputs after trade liberalization. This increase in profits comes from two potential sources. After trade liberalization but conditional on the same set of imported inputs, firm profits are as least as large as before. It makes strictly larger profits if there is a reduction in tariff on at least one of its imported inputs. Furthermore, the firm chooses to import a weakly larger set of imported inputs by proposition 3. It chooses to do so only if its profits increase, which is evident from the recursive algorithm.

However, who enjoys a bigger increase in profits in the face of the same tariff reductions is a much tougher question to answer. If the attention is restricted to firms that are new importers, then it is clear that the more productive firms have a larger increase in profits than the less productive ones. It is not clear, however, if one wants to compare profits of an existing importer with those of a new importer. It is possible that the former increase by more if additional assumptions on the natural advantage of foreign varieties over their domestic counterparts are imposed, or if the differential efficiency, *b,* is large enough.

3.6.4.5 Total Factor Productivity

For firm *i* with productivity above the no-import cutoff, its total factor productivity (TFP) is defined as:

$$
\begin{aligned}
TFP_i &\equiv \frac{y_i}{L_i^{1\;\;\phi} \exp\left\{\phi\left(\int_{J_i^{Z*}} \gamma_j \log Z_{ij} dj + \int_{J_i^{M*}} \gamma_j \log M_{ij} dj\right)\right\}} \\
&= \varphi_i \cdot \exp\left\{\phi \int_{J_i^{M*}} \gamma_j \log \varphi_i^b a_j dj\right\} \\
&= \varphi_i^{1+b\phi \int_{J_i^{M*}} \gamma_j dj} \cdot \exp\left\{\phi \int_{J_i^{M*}} \gamma_j \log a_j dj\right\}
\end{aligned}
$$

TFP is greater than φ_i because the use of imported inputs enhances firm productivity by a factor that is bigger than 1. It is also obvious that a firm with higher baseline productivity ends up with higher TFP. Specifically, the TFP ratio is given by:

$$\begin{aligned}
\frac{TFP_{i'}}{TFP_i} &= \frac{\varphi_{i'}^{1+b\phi\int_{J_{i'}^{M*}}\gamma_j dj} \cdot \exp\left\{\phi \int_{J_{i'}^{M*}} \gamma_j \log a_j dj\right\}}{\varphi_i^{1+b\phi\int_{J_i^{M*}}\gamma_j dj} \cdot \exp\left\{\phi \int_{J_i^{M*}} \gamma_j \log a_j dj\right\}} \\
&= \left(\frac{\varphi_{i'}}{\varphi_i}\right)^{1+b\phi\int_{J_i^{M*}}\gamma_j dj} \cdot \varphi_{i'}^{b\phi\int_H \gamma_j dj} \cdot \exp\left\{\phi \int_H \gamma_j \log a_j dj\right. \\
&\geq \left(\frac{\varphi_{i'}}{\varphi_i}\right)^{1+b\phi\int_{J_i^{M*}}\gamma_j dj} \\
&> \frac{\varphi_{i'}}{\varphi_i}
\end{aligned}$$

The first inequality holds with equality when $H = \varnothing$, and holds strictly otherwise. The second inequality holds strictly because the assumption results in a non-empty set J_i^{M*}.

For firm *i* with productivity lower than the no-import cutoff, its TFP is:

$$\begin{aligned}
TFP_i &= \frac{y_i}{L_i^{1\ \phi} \exp\left\{\phi \left(\int_0^1 \gamma_j \log Z_{ij} dj\right)\right\}} \\
&= \varphi_i
\end{aligned}$$

Since it does not import any foreign inputs, there is no productivity enhancing effect from imported inputs. Hence, its TFP is the same as its baseline productivity parameter, φ_i. It is then trivial to show that the TFP ratio between two firms that are both below the cutoff is $\frac{TFP_{i'}}{TFP_i} = \frac{\varphi_{i'}}{\varphi_i}$.

Trade liberalization increases firm-level TFP through the expansion of the set of imported inputs. Again, suppose this trade liberalization induces a reduction in no-import cutoff, as in the first case in proposition 1. First, consider a firm with productivity above the original cutoff. Before trade liberalization, its optimal set of imported inputs is J_i^{M*}. It expands to $J_i^{M'_*}$ with *H* being the difference between the two sets. Then the expansion in the optimal set of imported inputs induced by trade liberalization increases its TFP by a factor:

$$\frac{TFP_i'}{TFP_i} = \varphi_i^{b\phi\int_H \gamma_j dj} \cdot \exp\left\{\phi \int_H \gamma_j \log a_j dj\right\} \geq 1$$

Equality holds only when $H = \varnothing$;.

For a firm with productivity above the new cutoff but below the original cutoff, its TFP increases by a factor:

$$\frac{TFP_i'}{TFP_i} = \varphi_i^{b\phi \int_{J_i^{M*\prime}} \gamma_j dj} \cdot \exp\left\{\phi \int_{J_i^{M*\prime}} \gamma_j \log a_j dj\right\} > 1$$

because its set of imported inputs expands from null set to $J_i^{M'_*}$. And further, $J_i^{M'_*}$ is weakly increasing in firm productivity for such a firm by proposition 2. So, for a newly importing firm, the increase in TFP is increasing in its baseline productivity. Trivially, for a firm that never imports, there are no TFP gains from trade liberalization.

However, it is not straightforward to compare the increase in TFP of two arbitrary firms, either both are existing importers or one is a new importer while the other is an existing importer. That depends on the expansion of the set of imported inputs induced by trade liberalization, and on the parameter *b*, which governs the degree of differential efficiency among firms in using foreign inputs. In general, a more productive firm has smaller room to expand its set of imported inputs. However, this constraint can be alleviated by a large *b* - that is, it is also much more efficient in using the higher quality foreign inputs.

3.7 Conclusion and Future Work

In this chapter, a partial equilibrium, heterogeneous firm model with endogenous imported inputs and labor quality choice is developed, and a link between an improvement in firm performance and the use of imported inputs is established. The model further predicts that firms that upgrade their intermediate inputs also upgrade their labor quality, resulting in higher wages. Combining the Annual Survey of Industrial Firms and Chinese Customs Data, the study is able to provide some stylized facts, which support the model's predictions.

There are some issues that have not been addressed and are left as future work. First, an empirical test of the output quality upgrading hypothesis proposed in Broda and Weinstein (2006) can be important. Second, the model can be extended to accommodate variable markups, and then its prediction about firm markup distribution can be empirically tested. Third, it would be interesting to look into firm ownership structure more carefully so that more can be said about the mechanism that generates the link between firms profits and wage inequality that is observed in the data.

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APPENDIX A

Appendix for Chapter 1

A.1 Welfare Change as Equivalent Variation

Consider the set of changes $\left\{\widehat{p^h_{(j,n)}}\right\}_{(j,n)\in\mathcal{J}\times\mathcal{N}}$ and $\{\widehat{w_z}\}_{z\in\mathcal{Z}_h}$. The resulting change in the indirect utility is:

$$\widehat{v_z} = \sum_j \sum_n \frac{\partial \ln v\left(w_z, \mathbf{p}^h\right)}{\partial \ln p^h_{(j,n)}} \widehat{p^h_{(j,n)}} + \frac{\partial \ln v\left(w_z, \mathbf{p}^h\right)}{\partial \ln w_z} \widehat{w_z}$$

The equivalent variation, $\widehat{u_z}$,is the proportional change in income at the original prices to induce the same proportional change in indirect utility:

$$\widehat{v_z} = \frac{\partial \ln v\left(w_z, \mathbf{p}^h\right)}{\partial \ln w_z} \widehat{u_z}$$

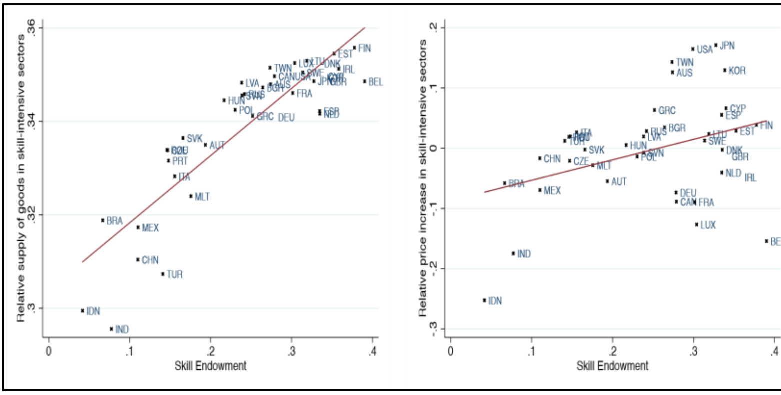
They imply, with the help of Roy's identity,

$$\widehat{u_z} = \widehat{w_z} + \sum_j \sum_n \left(\frac{\partial \ln v\left(w_z, \mathbf{p}^h\right)}{\partial \ln p^h_{(j,n)}} \Big/ \frac{\partial \ln v\left(w_z, \mathbf{p}^h\right)}{\partial \ln w_z} \right) \widehat{p^h_{(j,n)}} = \widehat{w_z} + \sum_j \sum_n \quad s^z_{(j,n)} p^h_{(j,n)}$$

A.2 Specialization in Production

An index of a region *n's* relative supply of goods in skill-intensive sectors is constructed as the following: $\frac{\sum_{j=1}^{J} \alpha_j\, supply(j,n)}{\sum_{j=1}^{J} supply(j,n)}$, where α_j denotes the skill intensity of a sector. As shown in **Figure A.1,** skill-abundant regions produce relatively more in skill-intensive sectors at equilibrium. In addition, an index of a region *n*'*s* relative price increase in skill-intensive sectors is constructed. As shown in Figure A.1, skill-abundant regions are found to experience a bigger increase in the relative price of skill-intensive goods after the trade liberalization.

Figure A.1: Specialization in Production and Price Changes



A.3 Gauss-Jacobi Algorithm and Property of the Equilibrium

The Gauss-Jacobi algorithm procedure reduces the problem of solving for n unknowns simultaneously in n equations to that of repeatedly solving n equations with one unknown. More specifically, given the known value of the kth iterate, x^k, one uses the ith equation to compute the ith component of unknown x^{k+1}, the next iterate. Formally x^{k+1} is defined in terms of x^k by the following equations:

$$f^1(x_1^{k+1}, x_2^k, x_3^k, ..., x_n^k) = 0$$
$$f^2(x_1^k, x_2^{k+1}, x_3^k, ..., x_n^k) = 0$$

...

$$f^n(x_1^k, x_2^k, ..., x_{n\quad 1}^k, x_n^{k+1}) = 0$$

The linear Gauss-Jacobi method takes a single Newton step to approximate the components of x^{k+1}.

Note that the set of prices enter both the demand side and the supply side nonlinearly. In general, for a system of nonlinear equations, it is not possible to characterize the conditions under which a solution exists or is unique. The Implicit Function Theorem is appealed to show that the price equilibrium that is found numerically using the Gauss-Jacobi method is locally isolated as a function of the parameters. It states that if F is continuously differentiable, if $F(x^*) = 0$, and if $DF(x^*)$ has full rank, then the zero set of F is, near x^*, an N-dimensional surface in R^L. The excess demand functions are continuously differentiable and the vector of prices set them to 0. Also, the Jacobian matrix of these functions has full rank (J *N = 1400).

APPENDIX B

Appendix for Chapter 2

B.1 Regions in IPUMS-I

Brazil (2000), Canada (2001), Colombia (1973), India (2004), Jamaica (2001), Mexico (2000), Panama (2000), United States (2005), Uruguay (2006), Venezuela (2001), Israel (1995), Germany (1970), Puerto Rico (2005), Indonesia (1995), South Africa (2007), Dominican Republic (2002).

B.2 Absolute Advantage A^h (λ)

$$x^h(\lambda) = \left(\sum_j x^h(\lambda, j)^{\theta(\lambda)}\right)^{\frac{1}{\theta(\lambda)}} = \left\{\sum_{j\in\mathcal{J}} \left[p^h_{(j,h)} A^h(\lambda) T(\lambda, j)\right]^{\theta(\lambda)}\right\}^{\frac{1}{\theta(\lambda)}}$$

$$= A^h(\lambda)\left\{\sum_{j\in\mathcal{J}} \left[p^h_{(j,h)} T(\lambda, j)\right]^{\theta(\lambda)}\right\}^{\frac{1}{\theta(\lambda)}}$$

$$log\, x^h(\lambda) = log\, A^h(\lambda) + \frac{1}{\theta(\lambda)} log \left\{\sum_{j\in\mathcal{J}} \left[p^h_{(j,h)} T(\lambda, j)\right]^{\theta(\lambda)}\right\}$$

Take a first-order approximation at p **= 1**, T **= 1**:

$$log\, x^h(\lambda) = log\, A^h(\lambda) + \frac{1}{\theta(\lambda)}\left\{log\, J + \frac{1}{J}\sum_{j\in\mathcal{J}}\left(\left[p^h_{(j,h)} T(\lambda, j)\right]^{\theta(\lambda)} - 1\right)\right\}$$

$$= log\, A^h(\lambda) + \frac{1}{\theta(\lambda)}\left\{log\, J + \frac{1}{J}\sum_{j\in\mathcal{J}} log\left(\left[p^h_{(j,h)} T(\lambda, j)\right]^{\theta(\lambda)}\right)\right\}$$

$$= log\, A^h(\lambda) + \frac{1}{\theta(\lambda)} log\, J + \frac{1}{J}\left[\sum_{j\in\mathcal{J}} log\, p^h_{(j,h)} + \sum_{j\in J} log\, T(\lambda, j)\right]\Bigg\}$$

$$log\, x^h(1) = log\, A^h(1) + \frac{1}{\theta(1)} log\, J + \frac{1}{J}\left[\sum_{j\in\mathcal{J}} log\, p^h_{(j,h)} + \sum_{j\in J} log\, T(1, j)\right]\Bigg\}$$

$$log\left(\frac{x^h(\lambda)}{x^h(1)}\right) = log\left(\frac{A^h(\lambda)}{A^h(1)}\right) + log\, J\left(\frac{1}{\theta(\lambda)} - \frac{1}{\theta(1)}\right) + \frac{1}{J}\sum_{j\in J} log\left(\frac{T(\lambda, j)}{T(1, j)}\right)$$

B.3 Labor Groups

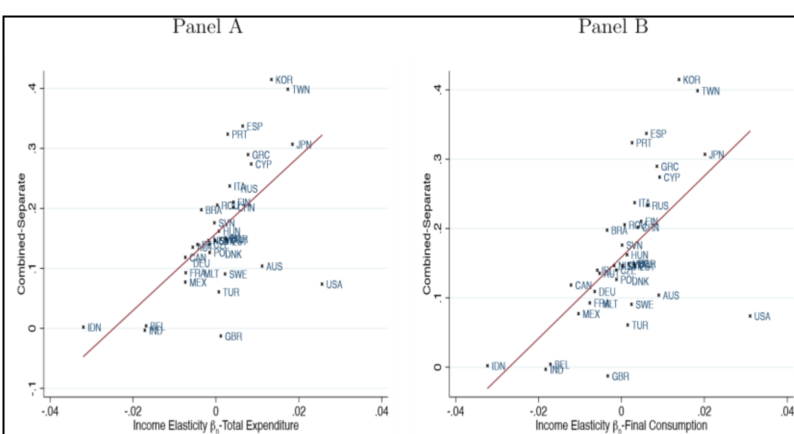
Table B.1: Labor Groups

labor group	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
sex	Male	Male	Male	Male	Male	Male	Male	Male	Male
age	15-24	15-24	15-24	25-49	25-49	25-49	50-74	50-74	50-74
edu	ED0-2	ED3-4	ED5-8	ED0-2	ED3-4	ED5-8	ED0-2	ED3-4	ED5-8
labor group	10	11	12	13	14	15	16	17	18
sex	Female	Female	Female	Female	Female	Female	Female	Female	Female
age	15-24	15-24	15-24	25-49	25-49	25-49	50-74	50-74	50-74
edu	ED0-2	ED3-4	ED5-8	ED0-2	ED3-4	ED5-8	ED0-2	ED3-4	ED5-8

B.4 Bias and Income Elasticity

Figure B.1 plots the difference in the poor's relative benefit from trade liberalization between estimating the two effects jointly and separately against the income elasticity of production of a region. Panel A uses the income elasticity computed from total expenditure while Panel B is restricted to final consumption. The correlation between the bias and the income elasticity of production of a region remains positive and significant after excluding Luxembourg. This implies that the interaction of the two channels benefits more the regions that produce high-income elastic goods.

Figure B.1: Underprediction of Pro-Poor Bias of Trade Liberalization Excluding Luxembourg



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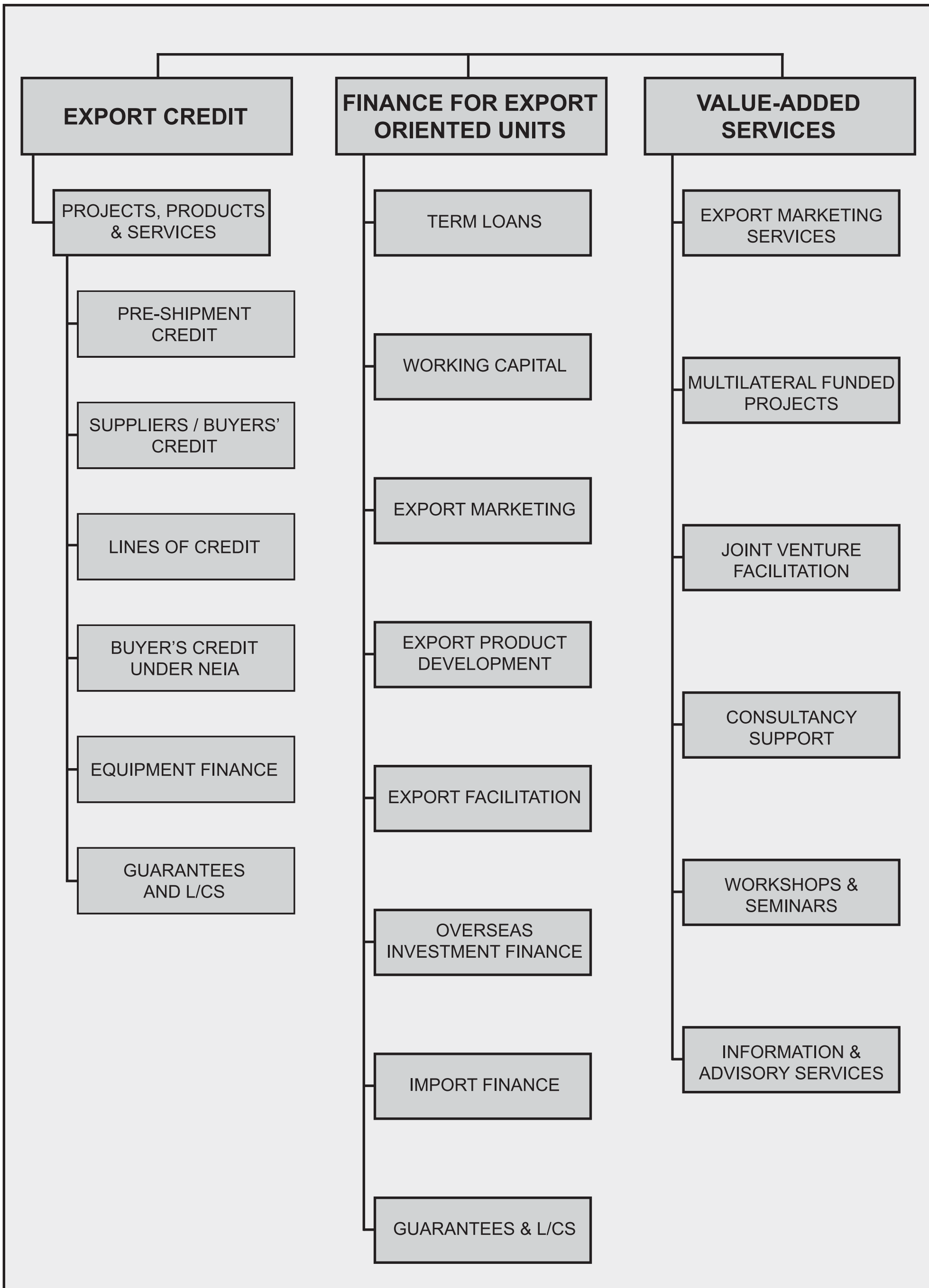
EXIM BANK'S MAJOR PROGRAMMES

Bank's Major Programmes



EXPORT-IMPORT BANK OF INDIA

HEAD OFFICE

Centre One Building, 21st Floor, World Trade Centre Complex, Cuffe Parade, Mumbai 400 005.
Phone: (91 22) 22172600 Fax : (91 22) 22182572
E-mail : ccg@eximbankindia.in Website: www.eximbankindia.in

LONDON BRANCH

5th Floor, 35 King Street, London EC2V 8BB United Kingdom
Phone : (0044) 20 77969040 Fax : (0044) 20 76000936 E-Mail :eximlondon@eximbankindia.in

DOMESTIC OFFICES

Ahmedabad

Sakar II, 1st Floor,
Next to Ellisbridge Shopping Centre,
Ellisbridge P. O.,
Ahmedabad 380 006
Phone : (91 79) 26576843
Fax : (91 79) 26578271
E-mail : eximahro@eximbankindia.in

Bangalore

Ramanashree Arcade, 4th Floor,
18, M. G. Road,
Bangalore 560 001
Phone : (91 80) 25585755
Fax : (91 80) 25589107
E-mail : eximbro@eximbankindia.in

Chandigarh

C- 213, Elante offices, Plot No. 178-178A,
Industrial Area phase 1,
Chandigarh 160 002
Phone : (91 172) 2641910
Fax : (91 172) 2641915
E-mail : eximcro@eximbankindia.in

Chennai

Overseas Towers,
4th and 5th Floor,
756-L, Anna Salai,
Chennai 600 002
Phone : (91 44) 28522830/31
Fax : (91 44) 25224082
E-mail : eximchro@eximbankindia.in

Guwahati

NEDFi House, 4th Floor, GS Road,
Dispur, Guwahati 781 006
Phone : (91 361) 2237607/609
Fax : (91 361) 2237701
E-mail : eximgro@eximbankindia.in

Hyderabad

Golden Edifice, 2nd Floor,
6-3-639/640, Raj Bhavan Road,
Khairatabad Circle,
Hyderabad 500 004
Phone : (91 40) 23379060
Fax : (91 40) 23317843
E-mail : eximhro@eximbankindia.in

Kolkata

Vanijya Bhawan, 4th Floor,
(International Trade Facilitation Centre),
1/1 Wood Street,
Kolkata 700 016
Phone : (91 33) 22891728/29/30
Fax : (91 33) 22891727
E-mail : eximkro@eximbankindia.in

New Delhi

Statesman House, Ground Floor,
148, Barakhamba Road,
New Delhi 110 001.
Phone : (91 11) 23326375
Fax : (91 11) 23322758
E-mail : eximndro@eximbankindia.in

Pune

44, Shankarseth Road, Pune 411 037.
Phone : (91 20) 26403000 / 26403106
Fax : (91 20) 26458846
E-mail : eximpro@eximbankindia.in

OVERSEAS OFFICES

Abidjan

5th Floor,
Azur Building,
18-Docteur Crozet Road,
Plateau,
Abidjan,
Côte d'Ivoire
Phone : (225) 20 24 29 51
Mobile : (225) 79707149
Fax : (225) 20 24 29 50
Email : eximabidjan@eximbankindia.in

Addis Ababa

House No. 46,
JakRose Estate Compound,
Woreda 07,
Bole Sub-city,
Addis Ababa,
Ethiopia.
Phone : (251 116) 630079
Fax : (251 116) 610170
E-mail : aaro@eximbankindia.in

Dhaka

Madhumita Plaza, 12th Floor,
Plot No. 11, Road No. 11, Block G,
Banani, Dhaka, Bangladesh - 1213.
Phone : (088) 0170820444
E-mail : eximdhaka@eximbankindia.in

Dubai

Level 5, Tenancy 1B,
Gate Precinct Building No. 3,
Dubai International Financial Centre,
PO Box No. 506541, Dubai, UAE.
Phone : (971 4) 3637462
Fax : (971 4) 3637461
E-mail : eximdubai@eximbankindia.in

Johannesburg

2nd Floor, Sandton City Twin Towers East,
Sandhurst Ext. 3, Sandton 2196,
Johannesburg, South Africa.
Phone : (27) 716094473
Fax : (27 11) 7844511
E-mail : eximjro@eximbankindia.in

Singapore

20, Collyer Quay, #10-02,
Tung Centre, Singapore 049319.
Phone : (65) 65326464
Fax : (65) 65352131
E-mail : eximsingapore@eximbankindia.in

Washington D.C.

1750 Pennsylvania Avenue NW,
Suite 1202, Washington D.C. 20006,
United States of America.
Phone : (1 202) 223 3238
Fax : (1 202) 785 8487
E-mail : eximwashington@eximbankindia.in

Yangon

House No. 54/A, Ground Floor,
Boyarnyunt Street, Dagon Township,
Yangon, Myanmar
Phone : (95) 1389520
Mobile : (95) 1389520
Email : eximyangon@eximbankindia.in