Essays on Trade, Inequality, and Gravity

by

Eldar Sehic

A thesis submitted in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

Department of Economics

University of Alberta

Abstract

This dissertation is composed of three essays that focus on trade's impacts on inequality. The first essay is an *empirical analysis of trade and trade partner inequality*, in the context of gravity, covering 128 exporters and 126 importers for years 1982-2000. It reveals import share's negative average effect on income per capita, export share's positive average effect on income per capita, differential effects of trade in favor of more developed countries, and inequality-inducing impact of contemporary trade. The second essay is an *empirical analysis of trade and intranational inequality*, covering 151 countries for years 1978-2010. It tests three major existing hypotheses that relate the effect of trade openness on intranational inequality. The analysis is then extended to test a non-linear hypothesis, which predicts that the effect of trade openness on intranational inequality is conditional on the level of trade openness. The results indicate that a U shape effect is significant with all three trade openness measures: export share, import share, and trade share. The third essay is a *theoretical analysis of trade and international inequality*, in the context of dynamic gravity. Key novel expressions are derived: balance condition and barrier-flow dynamic gravity relationship. The balance condition shows that growth of a country's market share and trade ease puts downward pressure on the market share and trade ease of other countries. The barrier-flow dynamic gravity relationship shows that relative trade flows growth rate is inversely proportional to relative trade barriers growth rate. The dissertation contributes to our understanding of trade's impacts on trade partner inequality, intranational inequality, and international inequality.

Acknowledgments

I am grateful for the valuable mentorship and feedback from my supervisor (Beyza Ural Marchand), committee members (Connie Smith, Li Zhou), and external readers (Rick Szostak, Runjuan Liu, Mehmet Ulubasoglu). Also, I am grateful for the stimulating discussions and support from my professors, colleagues, students, friends, and family. Ultimately, I am grateful for the perpetual joy and love from my parents, brother, and wife.

Contents

List of Tables

Chapter 1

Gravity and Trade Partner Inequality

1.1 Introduction

This essay is an empirical gravity analysis of trade's impacts on income per capita and income per capita inequality between trading partners. The gravity model has been very effective in modeling trade between regions. By utilizing size and distance, it aims to explain the trade attractions that occur between regions, and their relationship to income. Given that trade is related to income per capita values of trading partners, this paper asks: *how has trade affected income per capita and income per capita inequality between trading partners?*

The foundation of the gravity equation is rooted in the field of physics. Its application to social sciences can be traced back to Carey (1865) who analyzed migration flows. The popularity of the gravity equation within "social physics" is largely attributed to Stewart (1948), with an analysis of demographic gravitation. Subsequent works of Isard (1954), Savage and Deutsch (1960), Tinbergen (1962), J. Anderson (1979), and Bergstrand (1985) promoted the use of gravity, making important strides in the analysis of trade. While there are many approaches to applying the gravity model, this paper will mainly focus on empirically modeling trade partner inequality as a function of imports. The paper will also use the gravity approach to instrument for trade and model trade's effect on income per capita, similarly to Frankel and Romer (1999) who use cross-sectional data, and to Feyrer (2009) who uses panel data. I will first review the relevant literature dealing with the effect of trade on income per capita. The focus in the literature tends to be on the effect of trade share (exports plus imports as % of GDP) on income per capita, with a general assumption that a higher trade share on average raises the income per capita and lifts people out of poverty. However, it is important to recognize that trade may not necessarily make all countries better off. Furthermore, the effects of trade on welfare can differ significantly for imports and exports. In this paper, using panel gravity analysis, I analyze the effects of the import share and the export share on income per capita, as well as the effects of the bilateral import share on income per capita inequality between trading partners.

Under the Factor Price Equalization theorem, given identical constant returns to scale production technologies and given that both countries produce both goods, free trade in commodities will equalize relative factor prices through the equalization of relative commodity prices (Samuelson, 1948). Acemoglu and Ventura (2002) describe a model of world income distribution in which all countries share the same long-run growth rate due to terms of trade effects. Countries that accumulate capital faster than average experience terms of trade deterioration, which lowers the rate of return to capital and discourages capital accumulation. They predict a stable income distribution across countries and find that cross-country differences in economic policies, savings, and technology result in cross-country differences in incomes, but not in long-run growth rates. The variation in the world income distribution is determined by the forces that shape the strength of the terms of trade effects: degree of openness to international trade and extent of specialization. They also find that countries with lower rates of time preference (higher saving rates) have better technologies and higher relative incomes.

Trade is usually seen as a great tool for growth, which can theoretically raise the average welfare. However, it is important to recognize that trade brings many changes to the country's economy, with potential negative consequences, through its imports and exports. These consequences can be especially damaging for the less developed countries that are not economically strong and able to deal with the changes. Trade can benefit some factors much more than others, and it can even raise the welfare of some factors while lowering the welfare of others (Stiglitz, 2006). The trade-induced inequality can occur within countries (intranational inequality), between countries (international inequality), and between trading partners (trade partner inequality). The trade partner inequality can occur through various channels, such as differences in: endowments, specialization, returns to scale, trade barriers, and bargaining power.

Trade can increase trade partner inequality if the more developed partner gains more from trade than the less developed partner. The Heckscher-Ohlin (HO) model (Heckscher & Ohlin, 1991) predicts that the relatively abundant factor gains from trade. Hence, if a more developed country is relatively more abundant in skilled labor and a less developed country is relatively more abundant in unskilled labor, then greater trade benefits the skilled labor in the more developed country and the unskilled labor in the less developed country. Given that wages make up the GDP and that skilled labor receives higher wages than unskilled labor, then the GDP of the more developed country (largely made up skilled labor) receives more income than the less developed country (largely made up of unskilled labor). Greater trade can thus increase the wage inequality between the more developed (abundant in skilled labor) country and the less developed (abundant in unskilled labor) country. This can be intensified with specialization in final goods or with specialization in intermediate goods (through outsourcing). The unskilled labor abundant country specializing in unskilled labor intensive goods may not contribute to technological progress and investment as much as the skilled labor abundant country specializing in skilled labor intensive goods. Thus, the trade between the two countries, induced by the specialization in these goods, can lead to higher inequality between them. Also, if a country experiences increasing returns to scale in its trade sector, then greater trade can raise the inequality between the factor returns in the high production country and the factor returns in the low production country. The asymmetry of trade barriers between countries also allows one trading partner to benefit more from trade. Finally, more developed countries are also able to capture more favorable gains from trade, since they have more bargaining power in trade negotiations (Stiglitz, 2006).

This paper's analysis of trade's effects on income per capita is a contribution to the existing studies that build a gravity-based instrument for trade to deal with the endogeneity of trade's impact on income per capita. It is important to instrument for trade when modeling its effects on income per capita, due to the endogeneity arising from higher income per capita leading to higher trade. The gravity approach, based on the country's geographical attributes and relationships with trading partners, provides an instrument to identify the impact of trade on incomes. Unlike the previous cross-sectional studies (Frankel & Romer, 1999; Irwin & Terviö, 2002; Noguer & Siscart, 2005), I use panel data and control for country and time heterogeneity (using country and time fixed effects), which allows for a more precise estimate of the effect of trade on income per capita. Furthermore, in building the gravity-based instrument, I include dummies for common language, colonial link, and GATT/WTO membership, in addition to the other commonly used gravity variables (populations, areas, distance, and common border). Another contribution of my estimations in the first part of the paper is that I decompose trade into imports and exports. The existing studies focus on the effect of the trade share (exports plus imports as % of GDP) on income per capita, while I consider the import share (imports as % of GDP) and the export share (exports as % of GDP) to see the effects of the different types of trade. I also involve interactions of trade with development dummies to test for potential differential effects of trade. This goes beyond looking at the average effects of trade and acknowledges that the effects may differ for different levels of development. I also test the robustness of my estimations with the inclusion of additional geographical and institutional controls, such as latitude, tropical exposure, and International Country Risk Guide (ICRG) Index.

Then I extend the gravity-based analysis to model the effects of trade on income per capita inequality between trading partners. Since trade affects the incomes of trading partners, then it is also important to see how *differently* it affects the incomes of trading partners (how it affects the inequality between trading partners). While trade can induce inequality between trading partners, the inequality can induce trade between trading partners as well. For instance, differences between the comparative advantages of countries can be a reason for the countries to trade with each other. Perhaps one country may have a comparative advantage in capital-intensive goods, while another country may have a comparative advantage in labor-intensive goods. This positive effect of inequality on trade would create upward bias on the effect of trade. On the other hand, inequality between trading partners may even create downward bias on trade, since higher inequality may lead to changes in the types of trading partnerships and lower trade between certain trading partners. The volume and the content of trade may be affected over time. For instance, if one country experiences internal growth and develops new tastes as a result of rising income, then it may lower how much it imports from some of its old trading partners. To address the endogeneity of trade, I build a gravity-based instrument, while controlling for country-pair and time heterogeneity (using country-pair and time fixed effects). The instrument also includes relative populations and GATT/WTO membership. The use of relative populations accounts for the relative size of the trading partners, while the GATT/WTO membership dummy is not affected by the inequality between trading partners (while it affects inequality through trade). The robustness of the findings are also tested with the use of the instrument that I use in the income per capita analysis. Furthermore, I test the robustness of the impact of contemporary trade on inequality with the inclusion of the divergence of capital accumulation between trading partners, as well as with the inclusion of the dynamics of inequality. I conduct the trade partner inequality analysis using the *Theil's L Index* inequality measure, as well as the *Range* for robustness.

To conduct the empirical study, I augment the large Dutt and Traca (2010) dataset with data on import shares, export shares, populations, areas, and GDP per capita values, from the World Development Indicators (WDI) Database (The World Bank, 2013). This results in 207,156 country-pair observations, covering 128 exporters and 126 importers, for years 1982-2000. Throughout the analysis, in addition to fixed effects estimations, I also explore alternative estimators, such as: Poisson pseudo maximum likelihood (PPML), Tobit, Hausman-Taylor (HT), Arellano-Bond general method of moments (GMM), dynamic panel data (DPD), and Arellano-Bover/Blundell-Bond dynamic panel data (DPDSYS). After constructing a trade instrument based on a panel gravity dataset, I find that on average the effect of the import share on income per capita has been negative, while the effect of the export share has been positive. With both trade measures, the differential effects of trade on income per capita have been more favorable to the more developed countries. Furthermore, I find evidence that trade has increased the inequality between trading partners. These findings contribute to the literature by showing that: exports and imports can have different effects on income per capita; effects of trade can differ across different levels of development; and trade can increase the income per capita inequality between trading partners.

1.2 Background

The relevant empirical gravity literature has been extensive, mostly focusing on cross-sectional analysis, and more recently focusing on panel analysis. McCallum (1995) considers the level of regional bilateral trade involving Canadian provinces and U.S. states. Using cross-sectional data (for the year 1988), he estimates that trade between two provinces is roughly 22 times the trade between a province and a state. The central message of his study is that borders matter. However, the Canada-U.S. Free Trade Agreement became in effect only at the beginning of 1988, while the NAFTA became in effect in 1994. This puts the problematic estimate into context. Moreover, his conclusion is based on cross-sectional data, thus missing the crucial time variation. The omitted variable bias in McCallum's results is further discussed in J. Anderson and van Wincoop (2003).

In a key analysis of the effect of trade on income per capita, Frankel and Romer (1999) stress the importance of geographical characteristics. Specifically, they relate the bilateral trade share of the countries to the distance between them and their sizes (population and area). They also involve a landlocked dummy, a contiguity (common border) dummy, and interaction terms. Subsequently, they use the predicted bilateral trade shares to construct a total trade share for each country. They use this constructed trade share in place of the actual trade share, along with population and area, to explain income per capita. They find that the positive (though not very significant) effect of the constructed trade share on income per capita from using instrumental variable (IV) regressions is *larger* than the (significant) effect of the trade share when using ordinary least squares (OLS), highlighting the *downward* bias of OLS. The authors discuss the possible explanations for this surprising result. Their main explanation is sampling variation (a chance positive correlation between the instrument and the residual). The other explanation offered is that trade is an imperfect proxy for the other ways in which interactions between countries boost income. The measurement error leads to downward bias. However, the authors overlook the possibility that the OLS effect of trade is picking up the downward pressures on income per capita, which are actually positively correlated with trade.[1] Another criticism is given by Rodríguez and Rodrik (2000), who point out the low significance of trade share's effect. They further note that the significance of trade share's effect falls with the inclusion of distance from equator and fraction of area in tropics. These additional geographical characteristics may affect income per capita, and their exclusion may bias the effect of trade share on income per capita.

Irwin and Terviö (2002) apply the methodology of Frankel and Romer (1999) without the use of interaction terms. Furthermore, they apply two stage least squares (2SLS), for several years. Namely, they add the additional step of first regressing the actual trade share on the constructed trade share, the population, and the area. Then the predicted values are used in the second stage regression to represent the trade shares, which along with population and area, are used to explain income per capita. They find that the positive effect of the trade share from the 2SLS regressions is also generally *larger* than the effect from the OLS regressions (even more than the effect from the Frankel-Romer IV regressions). However, like the Frankel-Romer results, their results are generally not robust to the inclusion of latitude. Furthermore, their explanation for the downward bias of the OLS effect rests in the measurement error. They too overlook the explanation that the downward bias is possibly due to the negative impact of the country's characteristics which are positively associated with trade, but negatively associated with income per capita.

To examine and question the precision of previous results, Noguer and Siscart (2005) apply the methodology of Frankel and Romer (1999), building on the earlier contributions of Irwin and

[1]These pressures can be the result of instability, conflict, poverty, institutions, relations, and other elements which make the country's inputs cheap and consequently its cheap exports desirable. Therefore, the effect of trade (while boosting income per capita) is positively associated with characteristics which are negatively associated with income per capita. See Burtless (1995) and Acemoglu (2002).

Terviö (2002). They use a fuller (cross-sectional) dataset to find a more statistically significant positive effect of the constructed trade share on income per capita. They also find that the magnitude of the effect decreases with the inclusion of latitude (while still remaining bigger than the OLS effect). Furthermore, contrary to the findings of Rodríguez and Rodrik (2000), the lower effect of the trade share still maintains significance. They explain this by the superiority of their instrument (which uses the Frankel-Romer methodology, but with a fuller dataset). Moreover, they encourage the use of latitude and tropical exposure for robustness. They justify this by the high correlations between the two variables and the instrumented trade share. They also consider other institutional controls, such as the ICRG Index.

In a panel framework, Feyrer (2009) proposes a time-variant instrument, along with country and time fixed effects. This reduces the bias from time-invariant variables such as latitude and historically determined institutions. He involves distance by air and distance by sea, with the motivation of creating a better instrument and eliminating the bias from the static geographic and institutional factors found in Frankel and Romer (1999). However, his distance measures are affected by the technological change which affects each country's income per capita (some more than others), thus making the distance measures endogenous. After using the predicted level of trade as an instrument for trade, he also finds that the positive effect of trade on income per capita is bigger in the IV regression than in the OLS regression. While the use of country and time fixed effects reduces the omitted variable bias that the cross-sectional studies are afflicted with, the proposed instrument still suffers from endogeneity.

Adding the time dimension within the gravity framework enriches the analysis. In doing so, Mátyás (1997) uses country and time specific effects, stressing the importance of recognizing the unobserved heterogeneity, as well as the time effects among countries. Egger and Pfaffermayr (2003) also use country and time effects, along with country-pair effects, noting their significance. Cheng and Wall (2005) demonstrate how cross-sectional analysis ignores important unobserved country heterogeneity and leads to biased results. They encourage the use of country and time fixed effects. Fidrmuc (2009) looks at a sample of OECD countries (for 1980-2002), using country-pair effects, showing that the fixed effects models perform relatively well (in comparison to panel cointegration techniques), given the non-stationarity in bilateral trade and output. Also, fixed effects models help lower the bias of the effect of trade on income per capita by controlling for unobserved influences on income per capita (Baier & Bergstrand, 2007).

I contribute to the existing literature in several ways. First, I develop a more informative instrument for measuring the effect of trade on income per capita. It is more informative because it uses more observations coming from a panel gravity dataset covering 128 exporters and 126 importers during 1982-2000, and because the estimations control for unobserved heterogeneity (using fixed effects). The instrument is designed using the standard gravity variables of distance and size (population and area), as used in the existing literature. Following Irwin and Terviö (2002), the instrument is constructed without contiguity dummy interactions that are used by Frankel and Romer (1999) and Noguer and Siscart (2005). Instead of relying heavily on the contiguity dummy, I include dummies for common language, colonial link, and GATT/WTO membership. These additional exogenous variables are relevant determinants in predicting trade between trading partners, as also found by Dutt and Traca (2010), and they allow for the IV regressions to more precisely estimate the effect of trade on income per capita. Moreover, in this paper I decompose the effect of trade by estimating the effects of the import share and the effects of the export share on income per capita, while recognizing potential differential effects. I find that on average the effect of the import share on income per capita has been negative, while the effect of the export share has been positive. This decomposition is a significant result in regards to the positive effect of the trade share that previous studies have found. Also, unlike the previous studies, I include development dummies and reveal that the differential effects of trade have been skewed in favor of more developed countries. Furthermore, I provide a novel approach to the gravity model, by estimating the income per capita inequality between trading partners. I find evidence that trade has increased the income per capita inequality between trading partners. This paper thus serves as a contribution to the discussions of the benefits and costs of trade, and the implications of trade on the inequality between nations.

1.3 Framework

Estimations of the gravity equation using logs usually face problems with inefficiency, inconsistency, and the sensitivity to zeros. Many attempts to deal with zeros tend to cause bias, such as assigning zeros to trade values that are missing, or assigning a small constant to all "zeros" (Silva & Tenreyro, 2006; J. Anderson, 2011). Thus, trading partners with missing data who actually trade with each other are treated as having no or little trade between each other, which biases the effect of trade. Excluding the missing observations would be a reasonable choice, which is less costly than imposing values on the missing information. This is the approach I will take in this paper, and the approach taken by Linders and de Groot (2014), Martin and Pham (2008), and Westerlund and Wilhelmsson (2011), among others. The disadvantage is the loss of information, but the advantage is that it does not impose inaccurate trade flows. Using cross-sectional data, Silva and Tenreyro (2006) propose a Poisson pseudo maximum likelihood (PPML) estimator. Some additional available alternative estimators include: Heckman maximum likelihood, Tobit, Hausman-Taylor, Arellano-Bond general method of moments, dynamic panel data (DPD), Arellano-Bover/Blundell-Bond dynamic panel data (DPDSYS), Tobit-type Poisson pseudo maximum likelihood, Gamma pseudo maximum likelihood, non-linear least squares, and feasible generalized least squares. Choosing the most suitable estimator in estimating the elasticities usually depends on the specific dataset and the specification tests involved (Martínez-Zarzoso, 2013; Gómez-Herrera, 2013).

Given the data and the motivation of the analysis, in addition to the standard fixed effects estimators, I explore the following alternative estimators: Poisson pseudo maximum likelihood (PPML), Tobit, Hausman-Taylor (HT), Arellano-Bond general method of moments (GMM), dynamic panel data (DPD), and Arellano-Bover/Blundell-Bond dynamic panel data (DPDSYS). While the popular PPML estimator focuses on dealing with heteroskedasticity, it is not free from bias (Martin & Pham, 2008; Westerlund & Wilhelmsson, 2011; Martínez-Zarzoso, 2013). Tobit estimator is simple and useful for censoring, but it relies on random effects, lacks theoretical foundation, and is vulnerable to heteroskedasticity. (Martin & Pham, 2008). HT estimator may improve efficiency of the estimates, but it is problematic with unbalanced panels. (Egger & Pfaffermayr, 2004). Lastly, GMM (and its variations: DPD and DPDSYS) is often praised for its consistency when dealing with unobserved heterogeneity that is correlated with the lag of the dependent variable, but it can have drawbacks in its application and interpretation when dealing with unbalanced panels. (Arellano & Bond, 1991; Arellano & Bover, 1995; Blundell & Bond, 1998; Windmeijer, 2005; Baltagi, Egger, & Pfaffermayr, 2007).

The paper builds on the Frankel and Romer (1999) empirical methodology, which preceded a theoretical framework developed by J. Anderson and van Wincoop (2003). The theoretical model relates exports of country i to country j (X_{ij}), as a function of own and partner incomes (Y_i, Y_j), world income (Y), elasticity of substitution (σ), trade costs (t_{ij}), and outward (Π_i) and inward (P_j) multilateral resistance terms:

$$X_{ij} = \left(\frac{Y_i Y_j}{Y}\right)\left(\frac{t_{ij}}{\Pi_i P_j}\right)^{1-\sigma} \tag{1.1}$$

Since exports of country i to country j are imports of country j from country i, then applying it to imports of country i from country j as share of country i's output ($T_{ij} = X_{ji}/Y_i$) gives:

$$T_{ij} = \left(\frac{Y_j}{Y}\right)\left(\frac{t_{ji}}{\Pi_j P_i}\right)^{1-\sigma} \tag{1.2}$$

Therefore, import share depends on relative economic size and trade frictions between trading partners. We can then ask how trade, depending on relative economic size and trade frictions, affects the income per capita values and the inequality between them. The paper uses the empirical benchmark of Frankel and Romer (1999) in capturing relative economic size and trade frictions to predict trade, and then estimates trade's effect on income per capita.

To make an appropriate econometric specification, it is important to consider the available data and the purpose of the analysis (Head & Mayer, 2015). Following the empirical literature, such as Noguer and Siscart (2005), I omit income variables when predicting trade, mainly due to the strong endogeneity, and the form of the dependent variable. The main trade variable I use is the imports of country i from country j as share of country i's GDP (denoted by T_{ijt}). To provide a deeper analysis of the effects of trade on income per capita, I also consider the effect of exports, by expressing X_{jit} as the exports of country j to country i as share of country j's GDP.

When estimating the trade expression, for the purpose of estimating the subsequent income per capita expression, I include variables which directly influence the trade flows, in the spirit of gravity. Namely, I relate the trade variable to the populations of the trading partners (N_{it}, N_{jt}), their areas (A_i,A_j), and their country-pair vector of variables (Z_{ijt}). Including size variables (population and area) captures the effects they have on the trade between the partners, as higher size generally tends to put downward pressure on international trade, due to the availability of intranational trade. The country-pair vector of variables includes: trade partner distance, a language dummy, a common border dummy, a colonial dummy, and a GATT/WTO membership dummy. Distance is a common determinant of trade, as higher distance puts downward pressure on trade between countries (Disdier & Head, 2008). The dummy variables capture the differences in predicted trade between having the common characteristics and not having them.

The use of fixed effects complements the framework to suit the purpose and consistency of the estimation (Head & Mayer, 2015). Country and time fixed effects are used in the trade model for the subsequent estimation of trade's effect on income per capita (which uses country and time fixed effects). Country-pair and time fixed effects are used in the trade model for the subsequent estimation of trade's effect on income per capita inequality (which uses country-pair and time fixed effects). Thus, the trade specification expressed in (1.3) includes country fixed effects (γ_i, λ_j) and time fixed effects (δ_t), to control for the unobserved heterogeneity (correlated with the explanatory variables), and to be consistent with the subsequent income per capita specification in (1.5).

$$ln(T_{ijt}) = \theta_0 + \theta_1 ln(N_{it}) + \theta_2 ln(N_{jt}) + \theta_3 ln(A_i) + \theta_4 ln(A_j) + \theta_5 Z_{ijt} + \gamma_i + \lambda_j + \delta_t + w_{ijt} \quad (1.3)$$

The country fixed effects help control for the multilateral trade resistance terms (Rose & van

Wincoop, 2001). The time fixed effects provide controls for cyclical changes, thus minimizing the bias of the results (Baldwin & Taglioni, 2006). Also, I consider country interactions with time fixed effects ($\gamma_i\delta_t$, $\lambda_j\delta_t$). These additional fixed effects can potentially account for the heterogeneity that may not be accounted for by the individual country fixed effects. For instance, the unobserved country-specific characteristics may change over time, so the interactions try to capture the unobserved trend.

Since T_{ijt} represents the imports of country i from country j as a share of country i's GDP, then summing the predicted values ($ln(\hat{T}_{ijt})$) from (1.3) in their exponential form across partners j gives country i's *predicted* import share:

$$\hat{T}_{it} = \sum_j e^{ln(\hat{T}_{ijt})} \tag{1.4}$$

Modeling a country's income per capita (YPC_{it}) as a function of its import share (T_{it}), population (N_{it}), area (A_i), country fixed effects (γ_i), and time fixed effects (δ_t) can be represented as:

$$ln(YPC_{it}) = \alpha_0 + \alpha_1 T_{it} + \alpha_2 ln(N_{it}) + \alpha_3 ln(A_i) + \gamma_i + \delta_t + e_{it} \tag{1.5}$$

The above specification is similar to the one used by Frankel and Romer (1999), Irwin and Terviö (2002), and Noguer and Siscart (2005), with the major differences being presence of fixed effects, use of the import share, and recognition of differential effects of trade. Controlling for size (population and area) reduces the bias of trade, since population and area also influence income per capita. Also, the country fixed effects and time fixed effects control for the unobserved heterogeneity, further lowering the bias of trade. Expression (1.5) is then estimated using IV regressions, with the predicted import share from (1.4) as the instrument for the import share.

Moreover, I include interactions of trade with development dummy variables. Namely, dividing the sample into rough thirds based on income per capita gives three groups of development: low, medium, and high. Thus, I include a Medium Development (M.D.) dummy and a High Development (H.D.) dummy, to test for the potential differential effects of trade on the country's development (income per capita). This models the potential differences that trade can have on income per capita, and how trade can potentially increase inequality between countries due to its different effects on development. Also, I consider additional geographical and institutional controls as encouraged by Noguer and Siscart (2005) for robustness (even though these controls are more crucial in the absence of fixed effects). I include land % in tropics, latitude, and ICRG Index.

For additional analysis, I estimate the effect of the export share (X_{jt}) on income per capita. So if T_{ijt} in (1.3) is instead expressed as the imports of country i from country j (exports of country j to country i) as share of country j's GDP, which can be denoted as X_{jit}, then summing the predicted values ($ln(\hat{X}_{jit})$) in their exponential form across partners i gives an estimate of country j's *predicted* export share (instrument for the export share):

$$\hat{X}_{jt} = \sum_{i} e^{ln(\hat{X}_{jit})} \tag{1.6}$$

The paper also uses the gravity framework to explain trade partner inequality. I first estimate the trade specification using a fixed-effects (within-group) estimator with country-pair fixed effects (μ_{ij}) and time fixed effects (δ_t) for the purpose of maintaining consistency when I subsequently model trade partner income per capita inequality in (1.8), which also uses country-pair and time fixed effects. The use of country-pair fixed effects drops the country-pair time-invariant variables, but accounts for important unobserved country-pair heterogeneity (Egger & Pfaffermayr, 2003). The country-pair fixed effects are also useful in better capturing the asymmetric trade barriers (costs) that affect trade and trade partner inequality. To recognize relative size, as an alternative to using individual populations, I model trade as a function of relative populations (ratio of importer's population to exporter's population), denoted by N_{ijt}, since trade and trade partner inequality are more dependent on relative (rather than absolute) populations of trading partners. I also include a country-pair time-variant GATT/WTO membership dummy (M_{ijt}), while country-pair time-invariant variables (including relative areas) are captured by the country-pair fixed effects, as displayed in (1.7).

$$ln(T_{ijt}) = \pi_0 + \pi_1 ln(N_{ijt}) + \pi_2 M_{ijt} + \mu_{ij} + \delta_t + w_{ijt} \tag{1.7}$$

I quantify income per capita inequality as *Theil's L Index* and *Range* (described in the next section). To model the impact of imports of country i from country j as share of country i's GDP (T_{ijt}) on income per capita inequality (Q_{ijt}), I use a fixed-effects (within-group) estimator and control for relative populations (N_{ijt}), country-pair fixed effects (μ_{ij}), and time fixed effects (δ_t):

$$Q_{ijt} = \beta_0 + \beta_1 ln(T_{ijt}) + \beta_2 ln(N_{ijt}) + \mu_{ij} + \delta_t + u_{ijt} \tag{1.8}$$

Controlling for the population ratio acknowledges that population differences can influence the income per capita inequality between two countries, not just through the trade between them. The use of country-pair fixed effects is suitable for the specification, since trade partner inequality is a function of country-pair elements, and thus controlling for unobserved country-pair heterogeneity is helpful. Expression (1.8) is then estimated with IV regressions using predicted trade from (1.7) as the trade instrument. The inequality regression is thus consistent with the first stage regression (1.7), which regresses bilateral trade on country-pair variables, while controlling for country-pair and time fixed effects. I also estimate expression (1.8) while including the capital stock ratio (importer's capital to exporter's capital), to control for the inequality of capital accumulation.

1.4 Data

A large gravity dataset from Dutt and Traca (2010) contains 207,156 country-pair observations, covering 128 exporters and 126 importers over the 1982-2000 period. Their main sources are COMTRADE, CEPII, IMF Direction of Trade Statistics, and The World Bank WDI Database. Even though this is a relatively large dataset, there is still an undeniable selection bias that is inherent in datasets, as many countries with very low development are left out (since their data is not available). I use all the available complete observations of this unbalanced panel dataset, since balancing would create bias. Roughly 29% of the observations are missing a country-pair trade value. Those entries are left blank, and they are not included in the analysis. Converting the blank entries into zeros or some small arbitrary constants would create bias (Silva & Tenreyro, 2006; J. Anderson, 2011). Not having information about those trading partners is costly, but imposing wrong information on those trading partners is more costly. Hence, only complete observations can be reasonably included in the estimations, which leaves 146,149 observations available. I make use of the country-pair data for bilateral trade (imports), distance, language, border, colonial link, and GATT/WTO membership. I then augment the dataset by merging import shares, export shares, populations, areas, and GDP per capita values, from the WDI Database (The World Bank, 2013).

The paper's main bilateral trade variable is imports of country i from country j (exports of country j to country i) at time t, which I relate to the importer's GDP when estimating the bilateral import share (T_{ijt}), or to the exporter's GDP when estimating the bilateral export share (X_{jit}). The non-dummy variables include: real (constant 2000 U.S. dollars) income (GDP) per capita, population, surface area in km^2, and distance between i and j in km. The dummy variables include: language (1 if i and j have a common official language), border (1 if i and j share a border), colonial link (1 if i and j have a colonial link), and time-variant membership (1 if i and j are both members of GATT or WTO). Additional geographical and institutional controls for modeling income per capita, obtained from the Center for International Development (2001), include: land % in tropics, latitude, and ICRG Index. An additional control for modeling inequality is real capital stock from Easterly and Levine (2002). Table 1.1 presents the summary statistics of the available variables.

Given the amount of observations, there is quite a diversity in the values. For instance, Ln(nominal imports of i from j) has quite a large range, with a minimum value of -4.605 (Mali & Australia in 1984), and a maximum value of 12.342 (Canada & U.S.A. in 2000). Ln(partner distance between i and j in km) ranges from 2.349 (R. Congo & D.R. Congo) to 9.892 (Indonesia & Colombia). It is also interesting to note, judging from the means of the dummy variables, that most of the country-pair observations in the sample do not share a common language, common border, or colonial link, while most of them are both members of GATT or WTO.

Table 1.1: Summary Statistics

DESCRIPTION	#	MEAN	S.D.	MIN.	MAX.
Ln(nominal imports of *i* from *j*)	146149	2.155	3.169	-4.605	12.342
Ln(real income per capita of *i*)	200697	7.724	1.633	4.463	10.871
Ln(real income per capita of *j*)	200870	7.733	1.616	4.463	10.871
Ln(population of *i*)	206483	16.339	1.514	12.362	20.956
Ln(population of *j*)	206416	16.331	1.519	12.362	20.956
Ln(surface area of *i* in km^2)	204879	12.493	1.806	6.522	16.654
Ln(surface area of *j* in km^2)	204860	12.508	1.802	6.522	16.654
Ln(partner distance between *i* and *j* in km)	207156	8.689	0.795	2.349	9.892
Import share	199838	35.241	21.692	2.982	187.972
Export share	200035	32.908	23.209	2.525	192.337
Common official language dummy	207156	0.148	0.355	0	1
Common border dummy	207156	0.026	0.159	0	1
Colonial link dummy	207156	0.018	0.134	0	1
GATT/WTO (*i* and *j*) membership dummy	207156	0.612	0.487	0	1
Land % in tropics	203114	0.501	0.474	0	1
Latitude	203114	20.114	25.010	-41.814	74.703
ICRG Index	171854	5.780	2.289	2.271	9.984
Ln(real capital of *i*)	53262	25.099	1.860	19.319	29.204
Ln(real capital of *j*)	52951	25.075	1.867	19.319	29.204

NOTES: Data source for country-pair variables (imports of *i* from *j*, distance, language, contiguity, colonial link, and GATT/WTO membership) is Dutt and Traca (2010). Data source for country variables (total imports, total exports, income (GDP) per capita, population, and area) is WDI Database (The World Bank, 2013). Nominal values are all in current U.S. dollars. Real GDP is in constant 2000 U.S. dollars. Partner distance is in km measured as distance from the partner's centers. Import share is 100*Imports/GDP, while Export share is 100*Exports/GDP. Common official language dummy is 1 if *i* and *j* have a common official language (0 otherwise). Common border dummy is 1 if *i* and *j* share a border (0 otherwise). Colonial link dummy is 1 if *i* and *j* have a colonial link (0 otherwise). GATT/WTO membership dummy is 1 if *i* and *j* are both members of GATT or WTO (0 otherwise). Additional controls are obtained from the Center for International Development (2001). Land % in tropics captures percent land area in the geographic tropics. Latitude is the latitude of country's centroid. ICRG Index (1982) is an indicator of quality of institutions. Data for real capital is obtained from Easterly and Levine (2002).

To create development groups, I divide the sample based on the country's real income per capita into rough thirds with similar amount of observations: low ($87-944), medium ($945-5,214), and high ($5,215-52,628). The summary statistics for the three importer groups and the three exporter groups are in Table 1.2. The table shows that the average import share and the average export share both rise with the average income per capita. The variance of the import share and the variance of the export share also both rise with the average income per capita. This variability of trade is a reminder that it is important to acknowledge other important elements when modeling the effects of trade on development. It should be noted that for low and medium development countries the average import share is higher than the average export share, while for high development countries the average export share is higher than the average import share. Later I model the effects of trade on development, while accounting for the endogeneity of trade.

The inequality between country i and country j at time t (Q_{ijt}) can be represented in various ways. A relevant and comprehensive inequality measure is the *Theil's L Index*, capturing mean log

Table 1.2: Summary Statistics: Development Groups

GROUP	DESCRIPTION	#	MEAN	S.D.	MIN.	MAX.
LOW DEVELOPMENT	Ln(real income per capita)	66899	5.870	0.545	4.463	6.849
IMPORTER	Import share	66416	31.540	16.753	2.982	152.806
MEDIUM DEVELOPMENT	Ln(real income per capita)	66845	7.649	0.524	6.851	8.558
IMPORTER	Import share	65637	36.696	19.670	5.461	110.689
HIGH DEVELOPMENT	Ln(real income per capita)	66953	9.650	0.525	8.560	10.871
IMPORTER	Import share	65100	37.385	27.041	4.631	187.972
LOW DEVELOPMENT	Ln(real income per capita)	65119	5.871	0.544	4.463	6.849
EXPORTER	Export share	64650	24.933	16.402	2.525	127.555
MEDIUM DEVELOPMENT	Ln(real income per capita)	69880	7.660	0.515	6.851	8.558
EXPORTER	Export share	68764	34.561	19.632	3.930	121.311
HIGH DEVELOPMENT	Ln(real income per capita)	65871	9.651	0.526	8.560	10.871
EXPORTER	Export share	63983	38.838	29.772	6.598	192.337

NOTES: Data source is WDI Database (The World Bank, 2013). Sample is divided into rough development thirds (low, medium, high) based on the country's real (constant 2000 U.S. dollars) income per capita.

deviation, which applied to two non-log values (Y_{it} and Y_{jt}) becomes:[2]

$$Theil's\ L\ Index_{ijt} = ln\left(\frac{Y_{it}+Y_{jt}}{2}\right) - \frac{1}{2}ln(Y_{it}Y_{jt}) \tag{1.9}$$

Alternatively, for robustness, I consider the *Range* (a simpler inequality measure):[3]

$$Range_{ijt} = \frac{max(Y_{it},Y_{jt}) - min(Y_{it},Y_{jt})}{(Y_{it}+Y_{jt})/2} \tag{1.10}$$

The summary statistics of the two inequality measures applied to real income per capita are shown in Table 1.3, along with trade partner inequality examples. The two inequality measures have the same inequality examples for minimum inequality (Japan & Norway in 1999) and maximum inequality (D.R. Congo & Norway in 2000).

Table 1.3: Trade Partner Income Per Capita Inequality Summary Statistics

MEASURE	MEAN	S.D.	MIN.	MAX.
Theil's L Index inequality	0.491 (Dominican R. & Germany, 1998)	0.497	0.000 (Japan & Norway, 1999)	2.343 (Norway & D.R. Congo, 2000)
Range inequality	1.232 (Trinidad-T. & Iran, 1989)	0.602	0.000 (Japan & Norway, 1999)	1.991 (Norway & D.R. Congo, 2000)

NOTES: $Theil's\ L\ Index_{ijt} = ln\left(\frac{Y_{it}+Y_{jt}}{2}\right) - \frac{1}{2}ln(Y_{it}Y_{jt})$ and $Range_{ijt} = \frac{max(Y_{it},Y_{jt})-min(Y_{it},Y_{jt})}{(Y_{it}+Y_{jt})/2}$ for given real (constant 2000 U.S. dollars) income per capita values (Y_{it}, Y_{jt}). There are 194,604 real inequality values.

[2] Given values $Y_1, Y_2, ...Y_N$ and their mean $\bar{Y} = \frac{1}{N}\sum_i^N Y_i$, *Theil's L Index* is given by: $\frac{1}{N}\sum_i^N ln\left(\frac{\bar{Y}}{Y_i}\right)$.

[3] *Theil's L Index* is generally a more comprehensive and common inequality measure than *Range*, since it is affected by middle values and transfers that occur between the minimum and the maximum values.

1.5 Results

1.5.1 Trade

This section estimates expressions (1.3) and (1.7), which relate imports of country *i* from country *j* as share of GDP_i to relevant gravity variables. Results are presented in Tables 1.4 and 1.5.[4] Out of the specifications using country and time fixed effects, specification [1] of Table 1.4 is most significant and consistent with gravity theory. Importer's population increases the bilateral import share by 0.72%, while exporter's population decreases it by 0.55%. Importer's area decreases the bilateral import share by 3.74%, while exporter's area decreases it by 2.10%. Signs of the effects are consistent with the findings by Frankel and Romer (1999) and Noguer and Siscart (2005).[5]

The differences in the effects of size across specifications are largely due to the form of fixed effects. For instance, the effect of the exporter's population is negative in specification [1], while it is positive in specification [3]. Specification [1] uses country and time fixed effects, while specification [3] uses country and time fixed effects, along with the interaction between exporter's fixed effects and time fixed effects. Using country fixed effects helps control for the multilateral trade resistance terms from expression (1.1) of gravity theory (Rose & van Wincoop, 2001). So when controlling for these terms, the negative effect of exporter's population is significant and consistent with gravity theory. Higher exporter's population reduces the need for international trade due to a higher incidence of intranational trade. The time fixed effects help control for cyclical changes (Baldwin & Taglioni, 2006). The interactions of the time fixed effects with the country fixed effects are causing the population coefficients to be unstable since populations are creating most of the time variation, while the other explanatory variables (except the membership dummy) are time-invariant. The positive effect of the importer's population is also evident in

[4]The use of interactions between time and importer fixed effects along with interactions between time and exporter fixed effects simultaneously was not executable due to the large number of countries and years.

[5]Note that Frankel and Romer (1999) and Noguer and Siscart (2005) use *i* to denote exporter and *j* to denote importer, while I use the opposite notation, since *i* is importing from *j*. Moreover, they use the total bilateral trade between partners, while I use unidirectional trade (import share and export share separately), consistent with recent literature and the subsequent estimations of income per capita and inequality. Also, I use country and time fixed effects with a larger dataset, so some results are expected to be different.

Table 1.4: Bilateral Import Share

DEPENDENT VARIABLE	Ln(imports of i from j as share of GDP$_i$)				
SPECIFICATIONS	[1]	[2]	[3]	[4]	[5]
Ln(population of i to j)					0.668*** (0.034)
Ln(importer's population)	0.722*** (0.072)	-0.311 (513.761)	0.441*** (0.072)	1.275*** (0.039)	
Ln(exporter's population)	-0.552*** (0.080)	-0.386*** (0.081)	1.673*** (0.305)	-0.041 (0.039)	
Ln(importer's surface area)	-3.738*** (0.767)	-0.044 (174.367)	-3.634*** (0.766)	-3.597*** (0.574)	
Ln(exporter's surface area)	-2.101** (0.856)	-2.051** (0.855)	-0.128 (0.173)	-1.047* (0.549)	
Ln(partner distance)	-1.264*** (0.008)	-1.265*** (0.008)	-1.265*** (0.008)		
Common language dummy	0.597*** (0.016)	0.593*** (0.016)	0.594*** (0.016)		
Common border dummy	0.436*** (0.030)	0.430*** (0.030)	0.433*** (0.030)		
Colonial link dummy	0.923*** (0.026)	0.923*** (0.026)	0.924*** (0.026)		
Membership dummy	0.010 (0.018)	-0.034 (0.025)	0.084*** (0.021)	-0.010 (0.013)	0.181*** (0.012)
Constant	84.315*** (16.388)	45.077 (6785.171)	24.477 -	34.174*** (10.076)	-3.923*** (0.009)
country fixed effects (γ_i and λ_j)	yes	yes	yes	no	no
country-pair fixed effects (μ_{ij})	no	no	no	yes	yes
time fixed effects (δ_t)	yes	yes	yes	yes	yes
interaction i fixed effects ($\gamma_i\delta_t$)	no	yes	no	no	no
interaction j fixed effects ($\lambda_j\delta_t$)	no	no	yes	no	no
observations	141511	141511	141511	141511	141511
Root-MSE	1.61	1.59	1.59	1.00	1.00

NOTES: Estimations of equations (1.3) and (1.7) for Trade are done using fixed effects; country and time dummies are used in regressions [1]-[3], while within-group estimator is used in regressions [4]-[5] with country-pair groups and time; dependent variable is Ln(100*(imports of i from j)/GDP$_i$); non-dummy explanatory variables include: Ln of population of i, Ln of population of j, Ln of population of i to j, Ln of surface area of i in km^2, Ln of surface area of j in km^2, and Ln of partner distance between i and j in km; dummy explanatory variables include: language (1 if i and j have a common official language), border (1 if i and j share a border), colonial link (1 if i and j have a colonial link), membership (1 if i and j are both members of GATT or WTO); robust standard errors are in parentheses; * p<0.1, ** p<0.05, *** p<0.01

specification [4], which uses country-pair fixed effects instead of country fixed effects. The effects of surface areas also vary due to the different uses of fixed effects, but less so than populations, due to their time-invariant nature. The negative effects of surface areas are also evident. Higher surface areas reduce the need for international trade due to a higher chance for intranational trade.

Table 1.5: Bilateral Import Share: Alternative Methods

DEPENDENT VARIABLE	Imports of i from j as share of GDP$_i$				
SPECIFICATIONS	[1]	[2]	[3]	[4]	[5]
Lag of dependent variable				0.345*** (0.005)	0.483*** (0.005)
Ln(importer's population)	-0.453*** (0.095)	-0.008 (0.057)	-0.133** (0.054)	0.115*** (0.037)	0.012 (0.029)
Ln(exporter's population)	0.282* (0.167)	0.552*** (0.087)	-0.118** (0.055)	0.220*** (0.041)	0.545*** (0.031)
Ln(importer's surface area)	-5.015*** (0.955)	-4.905*** (0.876)	-2.687*** (0.634)	-2.152*** (0.539)	-0.887*** (0.040)
Ln(exporter's surface area)	2.050 (1.911)	1.963 (2.677)	0.304 (0.190)	0.002 (0.576)	1.355*** (0.063)
Ln(partner distance)	-0.988*** (0.011)		-0.351*** (0.009)	2.526** (1.164)	1.278*** (0.117)
Common language dummy	0.423*** (0.022)		0.105*** (0.014)		8.732*** (0.317)
Common border dummy	0.084** (0.032)		0.516*** (0.044)		-2.408*** (0.728)
Colonial link dummy	0.963*** (0.031)		1.018*** (0.052)		-21.668*** (0.557)
Membership dummy	0.097*** (0.027)	0.160*** (0.021)	0.044*** (0.012)	-0.053*** (0.012)	-0.075*** (0.013)
Constant	50.052 (30.671)		41.013*** (10.020)		-26.696*** (1.340)
method	PPML	PPML	Tobit	GMM	DPDSYS
country fixed effects (γ_i and λ_j)	yes	no	no	no	no
country-pair fixed effects (μ_{ij})	no	yes	no	yes	yes
time fixed effects (δ_t)	yes	yes	no	yes	yes
observations	140859	139702	140859	106275	121162

NOTES: Estimations of equations (1.3) and (1.7) for Trade are done with the dependent variable being 100*(imports of i from j)/GDP$_i$; non-dummy explanatory variables include: one period lag of the dependent variable, Ln of importer's population, Ln of exporter's population, Ln of importer's surface area in km^2, Ln of exporter's surface area in km^2, and Ln of partner distance in km; dummy explanatory variables include: language (1 if i and j have a common official language), border (1 if i and j share a border), colonial link (1 if i and j have a colonial link), membership (1 if i and j are both members of GATT or WTO); robust standard errors are in parentheses; * p<0.1, ** p<0.05, *** p<0.01

Across the specifications, the effect of distance on trade is significant and robust. All else constant, a 1% increase in the partner distance has a predicted effect of lowering trade by 1.27%. This estimate is similar to some earlier findings, such as by: Frankel and Rose (2002), Rauch and Trindade (2002), Martínez-Zarzoso (2003), Rose (2004), and Disdier and Head (2008). The implication of the results is that distance puts downward pressure on trade, regardless of the other traits of the partners. Also, the effects of the three time-invariant dummy variables are robust across the specifications. Namely, trade between the partners is 60% higher if they share an official language, 44% higher if they share a border, and 92% higher if they have a colonial link. These estimates are generally robust across specifications, and similar to those of Dutt and Traca (2010), whose specifications differ from Table 1.4 (as they focus on the effects of corruption and bilateral tariffs on the bilateral trade).

The results from the alternative methods are presented in Table 1.5. The persistence effect of trade is significant, as indicated by the lag of the dependent variable, in the GMM and DPDSYS estimations. For the purpose of constructing the predicted import share as described in (1.4), specification [1] of Table 1.4 is preferred, as it is significant, in line with gravity theory, and consistent with the income per capita specification in (1.5) which also uses country and time fixed effects.[6] The correlation coefficients for actual and predicted bilateral import share increase with development: 78%, 83%, and 86% (for low, medium, and high, with development groups broken down as before by real income per capita). The overall correlation coefficient is 83%, which is strong due to the large panel dataset and the use of country and time fixed effects.

Specification [5] of Table 1.4, which estimates (1.7), is significant and consistent with the income per capita inequality expression in (1.8) which also uses country-pair and time fixed effects. It is worthy to note that the relative population of the importer to the population of the exporter has a positive effect on bilateral trade. So the bigger the importer is relative to the exporter in terms of population, the bigger the demand for imports (as % of importer's GDP). Specifically, a 1% increase in the population ratio increases the import share by 0.69%. This effect of the relative size of trading partners (in specification [5]) is more significant than the individual effects of the absolute size of trading partners (in specification [4]). Also, the significant membership dummy in specification [5] indicates that if both partners are members of GATT or WTO, then trade is predicted to be roughly 18% higher than if they are not both members. Given the significance of specification [5] and its use of country-pair and time fixed effects, it is the preferred first stage bilateral trade regression for the subsequent income per capita inequality IV regressions.

[6]Robustness tests were done using specification [3] as well, given its significance.

1.5.2 Income Per Capita

When estimating the effect of trade on income per capita, as expressed in (1.5), it is important to recognize the endogeneity of trade. As such, the import share is instrumented using the aggregation of the predicted bilateral import share values of specification [1] from Table 1.4, as expressed in (1.4). To test for differential effects of trade, I involve interactions of trade with the development group dummy variables. The inclusion of a Medium Development (M.D.) dummy and a High Development (H.D.) dummy accounts for differential effects of trade among the three development groups (which are divided as before into rough thirds based on real income per capita). For robustness tests, I include additional geographical and institutional controls. For additional analysis of trade's effects on income per capita, I analyze the effect of the export share on income per capita. The export share is instrumented using the aggregation of the predicted bilateral export share values, as expressed in (1.6). Tables 1.6 and 1.7 show the import share and the export share results from modeling income per capita using fixed effects. Specification [3] in each table uses all the available data from the WDI Database (for 184 countries), while the other specifications only include data with an available predicted trade share. Therefore, specification [3] also includes those (generally less developed) countries which are excluded in the other specifications (since they lack gravity data).

The IV results in Table 1.6 show that a higher import share has a negative average effect on income per capita, as found by Ondrich, Richardson, and Zhang (2003). As specification [4] shows, increasing the import share by 1 percentage point has an average effect of decreasing income per capita by 3.4%. Furthermore, the use of development dummies reveals differential effects of trade in favor of more developed countries. As specification [5] shows, the average effect on income per capita from increasing the import share of a low development country by 1 percentage point is -3.2%. The average effect is -2.5% for a medium development country, and -1.8% for a high development country. The differential effects are also present with the inclusion of geographical and institutional controls. The asymmetric trade effects are further confirmed in specification [3], which includes all the countries with actual import share values, but for which the predicted import

Table 1.6: Income Per Capita and Import Share

DEPENDENT VARIABLE	Ln(real income per capita)					
SPECIFICATIONS	[1]	[2]	[3]	[4]	[5]	[6]
Import share	0.000 (0.000)	-0.001** (0.001)	-0.003*** (0.001)	-0.034** (0.015)	-0.032** (0.013)	-0.007 (0.016)
Import share * M.D. dummy		0.002*** (0.001)	0.005*** (0.001)		0.007*** (0.002)	0.008*** (0.002)
Import share * H.D. dummy		0.004*** (0.001)	0.007*** (0.001)		0.014*** (0.002)	0.020*** (0.002)
Ln(population)	-0.740*** (0.059)	-0.682*** (0.059)	-0.474*** (0.056)	-1.231*** (0.240)	-0.956*** (0.213)	-0.736*** (0.090)
Ln(surface area)	0.094** (0.038)	0.107*** (0.038)	0.152*** (0.037)	-0.118 (0.140)	-0.037 (0.123)	0.405*** (0.080)
Land % in tropics						-1.160** (0.503)
Latitude						0.005 (0.004)
ICRG Index						0.280*** (0.042)
Constant	19.892*** (0.658)	18.512*** (0.711)	13.638*** (0.456)	33.977*** (6.320)	26.947*** (5.646)	12.310*** (2.888)
method	OLS	OLS	OLS	IV	IV	IV
country fixed effects (γ_i)	yes	yes	yes	yes	yes	yes
time fixed effects (δ_t)	yes	yes	yes	yes	yes	yes
observations	1858	1858	3012	1858	1858	1579
countries	120	120	184	120	120	88
Root-MSE	0.12	0.12	0.15	0.29	0.25	0.13
F statistic on $\hat{T}_{it}$ (first stage)	-	-	-	58.60	44.79	15.27

NOTES: Estimations of equation (1.5) for (importer's) Income per capita are done using country and time dummies (not reported); specification [3] uses all available data from the WDI Database, while the other estimations only use available data for countries with an available predicted import share; dependent variable is Ln of real (constant 2000 U.S. dollars) income per capita; non-dummy explanatory variables include: Import share (100*Imports/GDP), Ln of importer's population, Ln of importer's surface area in km^2, Land % in tropics, Latitude, ICRG Index; Medium Development (M.D.) dummy equals 1 if Ln(real income per capita) is greater than 6.850 and is lower than 8.559; High Development (H.D.) dummy equals 1 if Ln(real income per capita) is greater than 8.559; robust standard errors are in parentheses; * p<0.1, ** p<0.05, *** p<0.01; IV estimations use predicted import share ($\hat{T}_{it} = \sum_j e^{ln(\hat{T}_{ijt})}$), with predicted values of Ln(imports of i from j as share of GDP_i), denoted by $ln(\hat{T}_{ijt})$, from Table 4 Specification [1] seen below using country and time dummies (not reported)

$ln(\hat{T}_{ijt})$ = 84.315*** + 0.722*** Ln(importer's population) - 0.552*** Ln(exporter's population) - 3.738*** Ln(importer's surface area) - 2.101** Ln(exporter's surface area) - 1.264*** Ln(partner distance) + 0.597*** Common language dummy + 0.436*** Common border dummy + 0.923*** Colonial link dummy + 0.010 Membership dummy

N = 141511, Root-MSE = 1.61

share values do not exist (due to unavailable gravity data). Across the specifications, the effect of population on income per capita is negative, while the effect of surface area is generally positive, implying that having more people decreases income per capita, while having more land increases it, other things constant.

Table 1.7: Income Per Capita and Export Share

DEPENDENT VARIABLE	Ln(real income per capita)					
SPECIFICATIONS	[1]	[2]	[3]	[4]	[5]	[6]
Export share	0.002***	0.000	-0.000	0.026**	0.006	-0.015**
	(0.001)	(0.001)	(0.001)	(0.011)	(0.008)	(0.007)
Export share * M.D. dummy		0.001***	0.004***		0.004*	0.014***
		(0.001)	(0.001)		(0.002)	(0.003)
Export share * H.D. dummy		0.003***	0.006***		0.013***	0.024***
		(0.001)	(0.001)		(0.003)	(0.003)
Ln(population)	-0.719***	-0.671***	-0.439***	-0.503***	-0.452***	-0.666***
	(0.058)	(0.058)	(0.057)	(0.163)	(0.097)	(0.078)
Ln(surface area)	0.104***	0.117***	0.134***	0.372***	0.245***	0.334***
	(0.038)	(0.038)	(0.037)	(0.127)	(0.079)	(0.048)
Land % in tropics						-1.174***
						(0.092)
Latitude						0.006***
						(0.001)
ICRG Index						0.299***
						(0.014)
Constant	19.305***	18.103***	13.219***	10.173**	11.462***	12.154***
	(0.653)	(0.710)	(0.471)	(4.558)	(2.752)	(0.905)
method	OLS	OLS	OLS	IV	IV	IV
country fixed effects (λ_j)	yes	yes	yes	yes	yes	yes
time fixed effects (δ_t)	yes	yes	yes	yes	yes	yes
observations	1902	1902	3013	1902	1902	1612
countries	122	122	184	122	122	89
Root-MSE	0.12	0.12	0.15	0.22	0.14	0.14
F statistic on $\hat{X}_{jt}$ (first stage)	-	-	-	164.74	70.07	69.15

NOTES: Estimations of equation (1.5) for (exporter's) Income per capita are done using country and time dummies (not reported); estimation [3] uses all available data from the WDI Database, while the other estimations only use available data for countries with an available predicted export share; dependent variable is Ln of real (constant 2000 U.S. dollars) income per capita; non-dummy explanatory variables include: Export share (100*Exports/GDP), Ln of exporter's population, Ln of exporter's surface area in km^2, Land % in tropics, Latitude, ICRG Index; Medium Development (M.D.) dummy equals 1 if Ln(real income per capita) is greater than 6.850 and is lower than 8.559; High Development (H.D.) dummy equals 1 if Ln(real income per capita) is greater than 8.559; robust standard errors are in parentheses; * p<0.1, ** p<0.05, *** p<0.01; IV estimations use predicted export share ($\hat{X}_{jt} = \sum_i e^{ln(\hat{X}_{jit})}$), with predicted values of Ln(exports of j to i as share of GDP$_j$), denoted by $ln(\hat{X}_{jit})$, from the specification seen below using country and time dummies (not reported)

$ln(\hat{X}_{jit})$ = 92.692*** - 0.339*** Ln(importer's population) + 0.430*** Ln(exporter's population) - 0.522 Ln(importer's surface area) - 5.847*** Ln(exporter's surface area) - 1.263*** Ln(partner distance) + 0.598*** Common language dummy + 0.447*** Common border dummy + 0.912*** Colonial link dummy - 0.004 Membership dummy

N = 141511, Root-MSE = 1.61

Table 1.7 results show that the effects of the export share on income per capita are quite different from the effects of the import share (thus confirming the importance of decomposing the effects of the trade share). The IV results in specification [4] show that increasing the export share by 1 percentage point has an average effect of increasing income per capita by 2.6%. The use of development dummy variables again shows the presence of differential effects in favor of more developed countries. The positive average effect of the export share on a low development country is not significant. The differential effects of trade are again present with the inclusion of geographical and institutional controls. As specification [6] reveals, the differential effects are such that the effect of the export share is negative for a low development country and positive for a high development country. The use of differential effects in specification [6] reveals what is hidden by just looking at the average effect in specification [4]. Since specification [4] is giving the average effect of all the countries, and since more developed countries export more (as shown in Table 1.2), then their positive effect of the export share largely influences the average effect of the export share, thus making it positive. However, in specification [6] the negative coefficient for less developed countries is present since their ability to export (albeit less than more developed countries, as shown in Table 1.2) comes with high relative imports (since they import more than they export compared to more developed countries, as shown in Table 1.2), and thus the negative effect of imports is present for the less developed countries. The asymmetric trade effects are also revealed in specification [3], which includes all the 184 countries that have actual export share values. It should also be noted that the negative effect of population, positive effect of surface area, negative effect of land % in tropics, positive effect of latitude, and positive effect of ICRG Index are all consistent with existing literature and generally significant across the specifications in Tables 1.6 and 1.7.

The larger effect of instrumented export share over actual export share is consistent with the studies by Frankel and Romer (1999), Irwin and Terviö (2002), and Noguer and Siscart (2005) who analyze the effect of the trade share. As discussed, the smaller coefficient of actual export share reflects its positive correlation with the downward pressures on income per capita. Overall, the results of the income per capita analysis conducted here are significant: the average effect of the import share is negative, the average effect of the export share is positive, and the differential effects of trade are in favor of more developed countries. These findings have important implications regarding trade's effects on income and inequality.

1.5.3 Inequality

This section models the effect of trade (imports of i from j as share of GDP_i) on income per capita inequality between trading partners, as expressed in equation (1.8). Consistent with the trade expression in equation (1.7), I use a fixed-effects (within-group) estimator with country-pair and time fixed effects, which also allows me to control for relative populations. Trade in the IV regressions is instrumented with predicted trade from specification [5] of Table 1.4. Trade partner inequality results are presented in Table 1.8, using the *Theil's L Index* measure, as well as the *Range* measure for robustness tests. The instrument's F statistics are higher than in some of the first stage regressions in related literature, because the instrument in Table 1.8 has more observations than the related literature, it controls for unobserved heterogeneity using country-pair fixed effects, and it uses relative populations, which are more significant than individual populations when using country-pair fixed effects.

The OLS estimations show a negative effect of trade (imports of i from j as share of GDP_i) on inequality. Actual trade is expected to exhibit downward bias on trade partner inequality, since non-trade elements (such as country characteristics not captured by country-pair fixed effects) can be positively associated with trade, but negatively associated with trade partner inequality (such as country's internal policies). Also, there can be reverse causality, where the higher inequality between trading partners causes the trade between them to be lower. For instance, if one trading partner (i) starts to experience a rise in income per capita (due to internal economic growth) that causes the trade partner inequality to rise, then this may decrease imports of the now more developed country (i) from some of its trading partners, denoted by j, as share of GDP_i (due to changing incomes, prices, lifestyles, policies, and other elements that determine trade). Rising average incomes in a country can alter the types of goods the country imports, away from less expensive goods towards more expensive goods supplied by another trading partner or supplied domestically. This can therefore cause the country that is experiencing a rise in its income per capita to import less from its old trading partner.

The IV estimations, which address the endogeneity of trade, show a significant positive effect

Table 1.8: Trade Partner Income Per Capita Inequality

DEPENDENT VARIABLE	Income per capita inequality between i and j							
SPECIFICATIONS	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Lag of dependent variable							0.929***	0.891***
							(0.002)	(0.001)
Ln(imports of i from j as share of GDP$_i$)	-0.004***	-0.002**	0.108***	0.075***	0.139***	0.236***	0.008***	0.007***
	(0.000)	(0.001)	(0.008)	(0.007)	(0.035)	(0.057)	(0.001)	(0.002)
Ln(population of i to j)	0.001	-0.002	-0.073***	-0.053***	-0.190***	-0.309***	-0.006***	-0.005***
	(0.009)	(0.011)	(0.007)	(0.006)	(0.048)	(0.079)	(0.001)	(0.002)
Ln(capital of i to j)					0.059***	0.100***		
					(0.016)	(0.027)		
Constant	0.507***	1.247***	0.930***	1.538***	0.901***	1.905***	0.072***	0.165***
	(0.002)	(0.003)	(0.030)	(0.028)	(0.105)	(0.175)	(0.004)	(0.007)
method	OLS	OLS	IV	IV	IV	IV	IV	IV
inequality measure (Q_{ijt})	Theil's L	Range	Theil's L	Range	Theil's L	Range	Theil's L	Range
country-pair fixed effects (μ_{ij})	yes	yes	yes	yes	yes	yes	yes	yes
time fixed effects (δ_t)	yes	yes	yes	yes	yes	yes	yes	yes
observations	139322	139322	138310	138310	21683	21683	127321	127321
country-pair groups	13069	13069	12057	12057	2451	2451	10586	10586
Root-MSE	0.056	0.087	0.129	0.120	-	-	0.020	0.032
F statistic on $ln(\hat{T}_{ijt})$ (first stage)	-	-	244.45	244.45	76.94	76.94	292.60	244.11

NOTES: Estimations of equation (1.8) for Income per capita inequality are done using fixed effects (within-group) estimator with country-pair groups and time; dependent variable is income per capita inequality (Theil's L Index or Range), using real (constant 2000 U.S. dollars) income per capita values of i and j; explanatory variables include: Ln(100*(imports of i from j)/GDP$_i$), Ln of population i to j, Ln of capital i to j; robust standard errors are in parentheses for regressions [1]-[2]; conventional standard errors, using derived variance estimator for generalized least-squares, are in parentheses for regressions [3]-[8]; * p<0.1, ** p<0.05, *** p<0.01; IV regressions use predicted bilateral import share ($ln(\hat{T}_{ijt})$) from Table 1.4 Specification [5] seen below using country-pair and time fixed effects

$ln(\hat{T}_{ijt})$ = -3.923*** + 0.668*** Ln(population of i to j) + 0.181*** Membership dummy

N = 141511, Root-MSE = 1.00

of trade (imports of i from j as share of GDP$_i$) on inequality, for both inequality measures. The results imply that higher trade has on average increased the income per capita inequality between trading partners. This complements the findings in the previous section which showed trade's differential effects on income per capita. Since the differential effects were on average skewed more favorably towards more developed countries, then higher trade puts pressure on the income per capita inequality between countries to rise. The results of the IV estimations also indicate that relative population of the importer to the exporter has a negative effect on inequality. This implies that trade partner inequality falls when the importer is more populated relative to the exporter, other things constant. While the relative population variable may suffer from bias due to endogeneity (since higher inequality may encourage migration and affect the relative population ratio between the trading partners), the presence of the relative population ratio is an important control to reduce the bias of the effect of trade on inequality (the main variable of interest). The positive effect of trade on inequality is robust with the inclusion of the relative capital stock of the importer to the exporter, as seen in specifications [5] and [6]. Therefore, even after controlling for the divergence in capital accumulation (which has a positive effect on inequality), trade has a significant positive effect on inequality.

Specifications [7] and [8] control for the lag of the dependent variable to acknowledge the dynamics of inequality. With the inclusion of the lag of inequality there is still a significant positive effect of trade on inequality. Hence, after accounting for the persistence of inequality, the results show that a 1% increase in the imports of i from j as share of GDP_i has a predicted average effect of increasing trade partner inequality by 0.008 units of the *Theil's L Index*, and by 0.007 units of the *Range*. An example of a 0.008 difference in the *Theil's L Index* is the difference between Canada-Venezuela inequality in 1995 of 0.219 and Canada-Mexico inequality in 2000 of 0.227. The results in this section acknowledge the significant persistence of trade partner inequality, and they confirm that contemporary trade has on average increased trade partner inequality.[7] Potential future research can explore the intensive margin (amount of trade) and the extensive margin (amount of trading partners) of supply-side structural gravity models, to estimate the impact of trade barriers on aggregate trade flows and income per capita values.

1.6 Conclusion

The focus of this paper's panel analysis is modeling trade's effects on income per capita and trade partner income per capita inequality in the context of gravity. With the available data covering 128 exporters and 126 importers over the years 1982-2000, the analysis shows that the bilateral

[7]Results are robust when trade is instrumented using Table 4 Specification [1] instead, while controlling for populations, areas, distance, and (country and time) fixed effects. Trade instrumented using Table 4 Specification [2] or [3] with country and time fixed effects interactions was not executable due to the large number of countries and years. Note that Table 4 Specification [5] is the preferred first stage specification, since it controls for country-pair and time fixed effects in line with the subsequent inequality specification.

import share generally falls with higher surface areas and distance, while it rises with higher relative populations. Also, the bilateral import share is generally higher if trade partners share a common language, common border, colonial link, or GATT/WTO membership. The paper then displays import share's negative average effect on income per capita and export share's positive average effect on income per capita. Trade share's decomposition using panel analysis is a relevant contribution to the related cross-sectional analyses that estimate trade share's average effect on income per capita (Frankel & Romer, 1999; Irwin & Terviö, 2002; Noguer & Siscart, 2005). Furthermore, with the use of development dummy variables the paper reveals differential effects of trade in favor of more developed countries, for both the import share and the export share. The asymmetric trade effects are also exhibited in the trade partner income per capita inequality analysis, which shows the important inequality-inducing impact of contemporary trade.

Chapter 2

Trade Openness and Intranational Inequality

2.1 Introduction

Extreme inequality is a source of inefficiency, which can prevent some people from participating in the economy and contributing to the society. If income is very unequally distributed, it may lead to social unrest, instability, mis-allocation of resources, and distorted incentives for investment. It is generally found that inequality harms investment and growth (Persson & Tabellini, 1994; Deininger & Squire, 1996; Furman & Stiglitz, 1998). This is a major issue within less developed countries, as it further stifles their growth (Barro, 2000). Also, the presence of inequality may be used as a reason to increase government spending, which can lead to higher debt and lower investment. Inequality can also harm growth through corruption (Glaeser, Scheinkman, & Shleifer, 2003; Alesina & Angeletos, 2005). Overall, the higher inequality allows those with higher wealth to buy power and to secure their wealth, which intensifies inequality, instability, and inefficiency (Stiglitz, 2013). Given the significant economic effects of inequality, this paper asks: *how has trade affected intranational inequality*?

This paper aims to model the effects of trade openness on intranational inequality.[1] I first review the relevant literature on the three main existing hypotheses, as pointed out by E. Anderson (2005), regarding the effects of openness on inequality: (1) openness increases inequality in *all* countries; (2) openness increases inequality only in *developed* countries (those with high income per capita); and (3) openness increases inequality only in *high non-labor to labor ratio* countries. There is considerable overlap between hypotheses 2 and 3, since more developed countries tend to also have high non-labor to labor ratios (especially capital to labor ratios). To make the third hypotheses more specific, I will focus on land abundance as the non-labor factor, since more developed countries are not necessarily more land abundant. Furthermore, I will also test alternative factor endowments, such as: natural resource endowment (proxied by hydrocarbon exports, as well as by natural resource rents), capital stock, and human capital endowment (proxied by tertiary to non-tertiary education ratio). After considering the three hypotheses, I then test a non-linear hypothesis applied to the effects of openness on inequality, to see whether *the effect of openness on inequality is conditional on the level of openness*.

The motivation for the non-linear hypothesis comes from the need to reconcile the existing negative, positive, and indefinite effects of trade openness on inequality. Earlier literature has attempted to model a common inequality response for both less open and more open countries, as discussed in the following section. With this paper, I empirically show that the effect of openness on inequality follows a U shape, such that the inequality response to openness is negative for less open countries and positive for more open countries. This U relationship can be explained through a number of channels. By the Heckscher-Ohlin (HO) model (Heckscher & Ohlin, 1991), when a country trades more, the demand for its relatively abundant factor rises, creating higher incomes for those factors.[2] Thus, when a relatively labor abundant country becomes more open, then the relative returns to labor increase, while the relative returns to capital decrease. This decreases the inequality within the country. Furthermore, the trade-induced welfare gains allow for capital

[1] E. Anderson (2005) offers three main reasons for studying the inequality-trade relationship: (1) if trade raises income, without affecting inequality, then it reduces absolute poverty; (2) trade liberalization is less likely if costs are concentrated on specific influential groups; (3) people care about income relative to others.

[2] A thorough analysis of the HO model in theory and practice is discussed by Leamer (1995).

accumulation, which makes the country more abundant in capital. The terms of trade decline and the inequality-reduction slows down. In the long-run, the comparative advantage may shift to capital intensive sectors, while import-competing sectors become relatively more labor intensive. This decreases the returns to labor, increases the returns to capital, and thus increases the inequality. The result is a U shape between openness and inequality.

The U shape empirical analysis is also consistent with predictions of the theoretical mechanism of Xu (2003), who constructs a North-South model, linking factor returns and terms of trade to explain the observed rising wage inequality in less developed countries following trade liberalization. In the model, tariff reduction in the South expands the import set and reduces inequality. Subsequently, the terms of trade decline, which increases the export competitiveness and the export set, which then increases inequality. The resulting U shape relationship between trade openness and inequality presents a theoretical motivation to evaluate whether the relationship holds true empirically for all available countries.

There are many other channels through which trade can affect the inequality within countries, as further discussed by Goldberg and Pavcnik (2007). Feenstra and Hanson (1996) show how the transfer of production activities and outsourcing from the North to the South can increase the inequality within both regions, by increasing the skill intensity of output in both regions. Additional sources for the rising inequality within countries can include increased import competition for monopolistic sectors and skill-biased technological changes (Sachs & Shatz, 1996). Furthermore, the traditional specific factors model predicts that free trade benefits the factor specific to the export sector, hurts the factor specific to the import sector, and has an ambiguous effect on the mobile factor (Davidson, Martin, & Matusz, 1999). This can create inequality between owners of capital and labor within a country. If returns to capital increase and returns to labor decrease, then inequality increases. In general, trade openness can raise inequality by exposing a country to many risks and changes that can cause transitionary unemployment and decrease the factor returns for owners of labor, especially the poor who are less able to deal with the negative consequences (Stiglitz, 2006). Hence, along with the benefits of trade openness for some owners of factors within a country, the effect of trade openness can also hurt owners of other factors within a country, and thus consequently affect the inequality within that country.

In this paper I contribute to the literature by testing the existing hypotheses and the non-linear hypothesis regarding the effects of trade openness on intranational inequality, while recognizing the endogeneity of trade openness (which many of the previous studies have ignored). Openness can be endogenous to inequality if the country's inequality influences its trade patterns (Goldberg & Pavcnik, 2007). For example, country's characteristics can give rise to high inequality which can lead to a cheap labor force and the creation of cheap exports (due to low costs of production). To address the potential endogeneity, I construct a predicted trade openness variable, similarly to Barro (2000), as a function of population and land. Population and land are generally exogenous to intranational inequality, but they affect trade. Using a larger panel dataset, I control for regional and time fixed effects, which gives a more precise trade openness instrument. Rather than just analyzing the effect of the trade share as a measure of trade openness (as most previous studies have done), I also analyze the export share (export openness) and the import share (import openness).

The paper's analysis is based on data from the WDI Database (The World Bank, 2013) covering 151 countries over the years 1978-2010, to test the three main hypotheses and the non-linear hypothesis. I run fixed effects regressions, while controlling for income per capita and inflation, to model the effects of trade openness (export share, import share, trade share) on intranational inequality (Gini coefficient). Accounting for the endogeneity of trade openness, I investigate whether the linear functional form assumption is justified in modeling the effects of trade openness on intranational inequality, or whether there exists a non-linear relationship. There is no evidence in support of the first hypothesis, and there is evidence contrary to the predictions of the second hypothesis. There is further evidence contrary to the predictions of the third hypothesis in the case of hydrocarbon endowments. The results indicate that the non-linear hypothesis (with a U shape) is significant for all three trade openness measures. Overall, the paper contributes to resolving existing conflicting ideas about the effects of trade openness on intranational inequality.

2.2 Background

The relationship between inequality and openness has been studied theoretically and empirically from micro and macro points of view. Contributions to understanding the relationship have been vast and significant. This paper will focus on the empirical macro effects of trade on intranational inequality. There are generally three major approaches to hypothesizing about the effect of openness on inequality, as pointed out by E. Anderson (2005). The first hypothesis is that higher openness increases inequality in all countries. The theoretical rationale behind this relationship lies in the variant of the HO model. As standard HO model predicts, higher openness raises the relative demand for skilled labor in relatively skilled labor abundant countries and the relative demand for unskilled labor in relatively unskilled labor abundant countries (Leamer, 1995; Feenstra & Hanson, 1997; Wood, 2002; E. Anderson, 2005; Goldberg & Pavcnik, 2007). This suggests that inequality should rise in relatively skilled labor abundant countries (more developed countries), and fall in relatively unskilled labor abundant countries (less developed countries). However, higher openness raises the relative demand for natural resources (assets which are usually unequally distributed) in countries with abundant natural resources, which are mostly less developed countries (Leamer, 1987). Therefore, both in the more developed countries and in the less developed countries, the rich can disproportionately benefit as a result of openness, which can lead to higher inequality (E. Anderson, 2005).

The second hypothesis is that higher openness increases inequality in more developed countries, but it decreases it in less developed countries. The theoretical basis for this relationship is founded on the standard version of the HO model. Namely, it assumes that more developed countries have an abundance of skilled labor, while less developed countries have an abundance of unskilled labor, and therefore openness should increase the inequality in more developed countries, and decrease it in less developed countries (Feenstra & Hanson, 1997; Wood, 2002; E. Anderson, 2005; Goldberg & Pavcnik, 2007).

The third hypothesis is that the effect of openness on inequality is dependent on the size of the country's non-labor factor endowments relative to its labor endowment. Specifically, a higher factor endowment (relative to labor endowment) puts upward pressure on inequality from a rise in openness (E. Anderson, 2005). The theoretical explanation for this hypothesis lies in the assumption that labor is a more equally distributed factor compared to other factors. Thus, higher openness raises the returns of the more unequally-distributed factors and puts upward pressure on inequality (Londoño, Spilimbergo, & Székely, 1999; Gourdon, Maystre, & De Melo, 2008).

There are various reasons why the three mentioned hypotheses may not hold. The first hypothesis (against the HO predictions) suggests that higher openness increases inequality in all countries. This may not hold if greater openness raises the relative demand for owners of unskilled labor (abundant in less developed countries), thus raising their incomes (in line with the HO predictions). This increased income may also then lead to their greater personal investment, thus further lowering inequality (E. Anderson, 2005). The second hypothesis, suggesting that higher openness increases inequality only in more developed countries, while it decreases inequality in less developed countries, may not hold if openness raises the relative demand for natural resources in countries abundant in (unequally distributed) natural resources, which are mostly less developed countries (Leamer, 1987). Hence, less developed countries may experience a rise in inequality as a result of the openness driven by the abundance of natural resources. Furthermore, the third hypothesis may not hold if the country's openness is not heavily linked to the relative supply of non-labor factor endowments. This can occur in less developed countries, where openness benefits labor more than the other factors of the economy, thus allowing labor (more equal factor) to spread the income more evenly than if the openness is directed towards the other (more unequal factors) of the economy. Also, if a country is relatively abundant in skilled labor and not abundant in non-labor factors, then higher openness would lead to higher inequality, despite its low non-labor endowment. Finally, there may be other inequality sources, such as gender inequality (Becker, 1971), government redistribution inequality (Rodrik, 1997), and spatial inequality (Fujita, Krugman, & Venables, 1999). The three hypotheses represent various channels that can simultaneously be present.

Most panel studies reject the first hypothesis, which predicts that higher openness increases inequality in all countries. Edwards (1997) relates the Gini to various trade protection indicators, including average tariffs (covering 44 countries from the 1970s to 1980s). He finds that trade *protection* has a positive effect on inequality. Higgins and Williamson (2002) use the Sachs and Warner (1995) Index to represent openness, and they use the Gini, as well as quartiles, to represent inequality. They do not find any indication of a positive effect of trade on inequality (covering 85 countries from the 1960s to 1990s). E. Anderson and White (2001) reach similar conclusions using the S&W (1995) Index and the Gini, as well as quantiles. Calderón and Chong (2001) use the trade share and the Gini to reject the positive relationship (covering 102 countries from 1960 to 1995). Their results suggest a negative relationship. Dollar and Kraay (2004) agree with their findings, using the trade share and the Gini, as well as quintiles (covering 137 countries from the 1960s to 2000s). Angeles-Castro (2011) also rejects the first hypothesis (covering 93 countries from 1980 to 1996). He finds that a higher trade share decreases the Gini.

Some panel studies have shown support for the first hypothesis. Barro (2000) uses the Gini and an adjusted trade share, filtered for the estimated effects on the trade share from the logs of population and land area. He finds that higher openness increases inequality (covering 86 countries from 1960 to 1990). With the S&W (1995) Index and the Gini, Lundberg and Squire (2003) also find support for the first hypothesis (covering 38 countries from the 1960s to 1990s). With a similar dataset, Chen (2007) also finds that higher openness increases inequality, using the trade share and the Gini (as well as quintiles of income). Overall, the literature provides mixed evidence. Some of the differences in the conclusions of the studies are likely due to the differences in: methods, variables, and samples. In fact, the difference in the findings could possibly have a lot to do with the country selection, which is also mentioned by E. Anderson (2005). For instance, Edwards (1997) uses a sample made up of 44 countries that are relatively less open, finding support for the negative relationship between openness and inequality. On the other hand, Lundberg and Squire (2003) use a sample of 38 countries that are relatively more open, finding support for the positive relationship between openness and inequality. The two results thus imply a possibility of a U shape relationship between openness and inequality. I minimize the selection bias by increasing the country sample, as I test all the mentioned hypotheses that model the effects of openness on inequality.

The studies by Edwards (1997), Higgins and Williamson (2002), and Dollar and Kraay (2004) reject the second hypothesis, which claims that higher openness increases inequality in more developed countries (those with high income per capita). Furthermore, Barro (2000) suggests that the opposite relationship may be true. He finds that for a high level of development, higher openness leads to lower inequality. However, Calderón and Chong (2001) and Gourdon et al. (2008) find some validity in the second hypothesis, suggesting that higher openness increases inequality in more developed countries. In relation to the conditional effect of openness on inequality, the third hypothesis depends on factor endowment relative to labor. Londoño et al. (1999) use various openness variables, and they find that for a country with a high endowment of population with higher education, or with a high land endowment, higher openness does in fact increase inequality, while it decreases inequality for a country with a high capital endowment (relative to labor). Fischer (2001) confirms those results using the S&W (1995) Index. Gourdon et al. (2008) use tariffs and find that higher openness increases inequality given a high relative endowment of skilled labor or a high relative capital endowment.

Another interesting approach has emerged in relation to the conditional effect of openness on inequality. It is the idea of modeling the effect of openness on inequality as conditional on the level of openness. Xu (2003), motivated by the rising inequality in less developed countries, builds a theoretical model that implies a U shape relationship between openness and inequality. Chen (2007) hints at the inverted-U curve (Kuznets, 1955) and its application to openness and inequality. Dobson and Ramlogan (2009) make the application to 18 Latin American countries from 1982 to 2000 using the trade share and the average tariff. They are motivated by the inverted-U hypothesis, but they do not find strong support for it. Therefore, with the available world data and the relevant variables, in this paper I aim to empirically model the effect of openness on inequality, to see if there is evidence of a non-linear relationship.

2.3 Framework

In modeling the relationship between trade openness and intranational inequality, I consider the three existing hypotheses and the non-linear hypothesis. The general specification is displayed below in (2.1) as a relationship between the inequality measure (Q_{it}), trade openness variable (T_{it}), interaction variable (W_{it}), control variables (Z_{it}), and fixed effects (ρ_r, δ_t). The interaction variable (W_{it}) represents income per capita (YPC_{it}), relative factor endowment (E_{it}), or trade openness (T_{it}). The specification includes regional fixed effects (ρ_r) and time fixed effects (δ_t).

$$Q_{it} = \beta_0 + \beta_1 T_{it} + \beta_2 T_{it} W_{it} + \beta_3 Z_{it} + \rho_r + \delta_t + u_{it} \tag{2.1}$$

The inequality measure (Q_{it}) will take the standard form of the Gini coefficient, as in all the relevant aforementioned studies. It is the favored inequality measure due to its simplicity and availability. It provides an index relating the population shares with the income shares. A higher Gini is an indication of a greater inequality. To test an alternative inequality measure, I will take the difference between the income share held by the highest 10% and the income share held by the lowest 10%, and denote it by $Q10$. This inequality measure is an alternative to the Gini, giving a rough picture of the gap between the richest decile and the poorest decile in the country. Alternatively, the gap between the top 20% and the bottom 20%, denoted by $Q20$, is considered as well. However, these alternatives do not satisfy the transfer sensitivity property of inequality measurement, while the Gini satisfies all the Pigou-Dalton's principles of inequality measurement (Dalton, 1920), including capturing the higher inequality resulting from regressive transfers.

The trade openness variable (T_{it}) will be based on alternative definitions to fully analyze and capture the effects of openness. I use different measures of openness to test the aforementioned hypotheses, and to see how different each openness measure is in affecting inequality. I consider export share of output, import share of output, and their sum (trade share of output). The trade share provides a standard measure of openness, as in Dollar and Kraay (2004) and Angeles-Castro (2011). Furthermore, using the export share and the import share separately can show if the results are mainly driven by the export sector or the import sector. The export sector and the import sector can have different effects on the returns to factors and their inequality.

The interaction variable (W_{it}) will differ by the hypothesis in question. For the first hypothesis there is no interaction with openness, so it is assumed that β_2=0. The implication of the first hypothesis is that the marginal effect of openness is linear. However, by the second hypothesis, if the effect of openness is conditional on the level of development, specifically income per capita ($W_{it} = YPC_{it}$), then openness cannot be expected to have similar effects on inequality in a developed country and in a developing country. Furthermore, the third hypothesis proposes that the conditional nature of the effect of openness on inequality hinges on the relative non-labor factor endowment of the country ($W_{it} = E_{it}$). I will explore several endowment variables: land, hydrocarbon exports, natural resource rents, capital stock, and tertiary education. For instance, in the case of land per capita, the third hypothesis predicts that the marginal effect of openness on inequality is negative in a country with a low relative land endowment, while it is positive in a country with a high relative land endowment. Land endowment per capita (inverse of population density) is a non-labor factor with data that is more available and less problematic than other non-labor factors. Land endowment per capita is also analyzed by Higgins and Williamson (2002), Londoño et al. (1999), E. Anderson and White (2001), and Fischer (2001). Considering hydrocarbon endowment and its interaction with trade openness is limited by data, but it could provide insight into whether the effect of trade openness on inequality is conditional on how hydrocarbon-endowed the country is. Natural resource rents could also provide additional insight to see if the endowment of natural resources is linked to inequality. Furthermore, capital per worker and tertiary to non-tertiary education ratio (skilled to unskilled ratio) provide standard interactions for testing the third hypothesis, as done by Londoño et al. (1999), Fischer (2001), and Gourdon et al. (2008). Finally, the paper's main contribution is documenting if the effect of openness on inequality is conditional on the level of openness ($W_{it} = T_{it}$). This tests a non-linear relationship between openness and inequality, which implies that the marginal effect of openness on inequality may differ between a less open country and a more open country. The four hypotheses analyzed in this paper are summarized in Table 2.1.

Table 2.1: Hypotheses

HYPOTHESIS	W_{it}	PREDICTION
first	-	β_1>0, β_2=0
second	YPC_{it}	β_1<0, β_2>0
third	E_{it}	β_1<0, β_2>0
fourth	T_{it}	β_1<0, β_2>0

The control variables (Z_{it}) are used to control for observable effects on inequality. The objective is to not use variables that are endogenous (and for which strong instruments do not exist), or variables that are subjective and likely have measurement errors. Therefore, I control for variables that have direct effects on inequality, since excluding them may lead to omitted variable bias. As such, income (GDP) per capita is an important variable, to control for the level of development which affects inequality (E. Anderson & White, 2001; Calderón & Chong, 2001; Dollar & Kraay, 2002; Lundberg & Squire, 2003; Chen, 2007; Gourdon et al., 2008). To capture the curvature of the income per capita, I also include its square, as some earlier studies have done (Londoño et al., 1999; Barro, 2000; Dobson & Ramlogan, 2009). The inclusion of income per capita squared implies that the effect of development on inequality depends on the level of development. Additionally, I include inflation as a control variable that affects the distribution of income (Edwards, 1997; E. Anderson & White, 2001; Dollar & Kraay, 2002; Lundberg & Squire, 2003; Dollar & Kraay, 2004; Gourdon et al., 2008; Dobson & Ramlogan, 2009; Angeles-Castro, 2011). Inflation hurts real wealth, especially harming the poor (Bhagwati & Srinivasan, 2002). Consequently, it affects the distribution of the economy's wealth. Some studies rely on controlling for the financial sector development in a country (Higgins & Williamson, 2002; Dollar & Kraay, 2002; Lundberg & Squire, 2003; Dollar & Kraay, 2004). However, such measures are not available for many countries in my sample, nor are they consistent in their measurement. Consequently, addition of this variable would be problematic.

Fixed effects aid in controlling for the unobserved heterogeneity across groups and time, thus minimizing the omitted variable bias. Fixed effects are more appropriate than random effects since the effects are correlated with the explanatory variables. Regional fixed effects would be helpful in providing an additional control for heterogeneity. With respect to regions, Higgins and Williamson (2002) and Barro (2000) use dummies for only two regions (Africa and Latin America). In this paper, I use seven regions as classified by the World Development Indicators (WDI) Database (The World Bank, 2013): East Asia & Pacific (EAAP), Europe & Central Asia (EACA), Latin America & Caribbean (LAAC), Middle East & North Africa (MEANA), North America (NA), South Asia (SA), and Sub Saharan Africa (SSA).

The upward bias from the potential endogeneity of trade can occur if a country's or region's trade is high due to its characteristics which raise its inequality. Endogeneity problems generally arise when using trade to explain growth (Frankel & Romer, 1999), but also when using trade to explain intranational inequality (Goldberg & Pavcnik, 2007). Instrumenting for trade is challenging, as previous studies have found. Many studies simply assume that trade openness is exogenous to inequality. However, openness can be endogenous to inequality if the country's inequality influences its trading arrangements. For instance, this can occur when the country's characteristics give rise to high inequality which can result in a cheap labor force, consequently attracting production and the creation of cheap exports (due to low costs of production). Therefore, the conditions that lead to higher inequality can also lead to higher trade openness, thus making it endogenous. To address the potential endogeneity, I construct a predicted trade openness variable, similarly to Barro (2000), as a function of population and land. Population and land are generally exogenous to inequality, but they affect trade. Higher population and area tend to put downward pressure on trade *between* countries, due to higher trade *within* countries. Hence, I use the predicted trade openness values to instrument for trade openness.

2.4 Data

The data availability for modeling the effect of trade openness on intranational inequality is irregular across countries and years. Nevertheless, in this paper I make use of the available unbalanced panels, since balancing would create bias. I use the data from the WDI Database (The

World Bank, 2013).[3] Additionally, it is a good source for the data on openness and the control variables used in this paper. Hence, most of the data used in this paper, except hydrocarbon exports and capital stock, is obtained from the WDI Database. There are a total of 807 observations, covering 151 countries from 1978 to 2010. Appendix A gives the summary for each country, with the average values for the key variables. The main variables I consider in this paper are the standard Gini coefficient, the income share held by the lowest 10%, the income share held by the lowest 20%, the income share held by the highest 20%, the income share held by the highest 10%, the trade share of output, the export share of output, and the import share of output. The real income per capita measures that I consider are the GDP per capita in constant 2000 U.S. dollars, and the GDP per capita in PPP constant 2005 international dollars. Land area in km^2 divided by population gives land per capita. The inflation rate is the annual % change in the GDP deflator, which can be represented as Ln(1+(inflation rate)/100). Natural resource rents are in PPP constant 2005 international dollars. The tertiary to non-tertiary education ratios are derived using data for the fraction of labor force with tertiary education. The data for hydrocarbon export share of output is from the International Monetary Fund (2007), while the real capital stock per worker data is from Easterly and Levine (2002). Table 2.2 gives the summary statistics for all observations that have both inequality and trade data, with further details in Appendix A.

Breaking down the countries into the seven regions (EAAP, EACA, LAAC, MEANA, NA, SA, SSA) reveals the regional heterogeneity. Table 2.3 gives the summary statistics for the key variables (with available trade and inequality values). The average Gini is the lowest in Europe & Central Asia (EACA), and the highest in Latin America & Caribbean (LAAC). The Gini has the lowest variance in Middle East & North Africa (MEANA), and the highest variance in Sub Saharan Africa (SSA). South Asia (SA) has the lowest average logs of trade share, export share, and import share. Europe & Central Asia (EACA) has the highest average logs of trade share and

[3] A potential source for inequality data is the United Nations University World Income Inequality Database (UNU-WIDER, 2008). Its dataset is compiled using many sources, thus offering many observations, but which can also be problematic. Different sources may use different methods in their measurements of inequality (for example: income vs. consumption), and so the measures can be inconsistent and arbitrary. Obtaining the data from a single source has a higher likelihood for consistency.

Table 2.2: Summary Statistics

DESCRIPTION	#	MEAN	S.D.	MIN.	MAX.
Gini coefficient	807	42.59	10.10	19.49	74.33
Income share held by the lowest 10%	807	2.26	1.13	0.02	5.43
Income share held by the lowest 20%	807	5.72	2.32	0.82	11.97
Income share held by the highest 20%	807	48.96	8.25	31.36	78.25
Income share held by the highest 10%	807	33.48	7.81	18.14	65.00
Trade share of output	807	77.92	41.09	12.68	316.36
Export share of output	807	35.89	20.54	3.28	169.03
Import share of output	807	42.02	22.72	5.46	147.32
Ln(real income per capita)	806	7.40	1.15	4.55	10.75
Ln(real income per capita, PPP)	805	8.44	0.94	5.65	11.12
Ln(1+(inflation rate)/100)	805	0.17	0.37	-0.03	3.34
Ln(population, thousands)	807	9.44	1.54	0.40	14.08
Ln(land area, thousands km^2)	807	5.52	1.79	-1.20	9.70
Ln(natural resource rents, PPP)	803	21.40	2.36	13.07	27.23
Ln(real capital per worker)	60	7.73	0.90	5.78	8.96
Tertiary to non-tertiary education ratio	298	0.26	0.19	0.01	1.17
Hydrocarbon export share of output	120	4.41	12.70	0.00	68.70

NOTES: Data source for hydrocarbon export share of output is International Monetary Fund (2007). Real capital per worker data is from Easterly and Levine (2002). Data source for all other variables is WDI Database (The World Bank, 2013). The summary statistics are calculated for all the observations in the dataset that have both inequality and trade data. Additional details are in the Appendix. Share of output is 100*Volume/GDP. Real PPP values are in PPP constant 2005 international dollars; Real income per capita is in constant 2000 U.S. dollars; Inflation rate is annual % change in the GDP deflator. Tertiary to non-tertiary education ratio is derived using data for the fraction of labor force with tertiary education.

Table 2.3: Summary Statistics: Regions

REGION	DESCRIPTION	#	MEAN	S.D.	MIN.	MAX.
EAAP	Gini coefficient	75	39.04	6.38	24.85	50.88
	Ln(trade share of output)	75	4.41	0.59	2.77	5.76
	Ln(export share of output)	75	3.71	0.60	2.20	5.13
	Ln(import share of output)	75	3.72	0.60	1.93	4.99
EACA	Gini coefficient	250	33.31	5.35	19.49	53.70
	Ln(trade share of output)	250	4.50	0.36	3.51	5.63
	Ln(export share of output)	250	3.69	0.41	2.35	5.01
	Ln(import share of output)	250	3.88	0.39	2.88	4.86
LAAC	Gini coefficient	286	51.95	5.56	34.42	63.30
	Ln(trade share of output)	286	4.02	0.59	2.62	5.54
	Ln(export share of output)	286	3.28	0.58	1.88	4.77
	Ln(import share of output)	286	3.35	0.63	1.70	4.92
MEANA	Gini coefficient	35	38.44	4.16	30.13	47.42
	Ln(trade share of output)	35	4.22	0.48	2.62	4.97
	Ln(export share of output)	35	3.42	0.52	1.37	4.05
	Ln(import share of output)	35	3.61	0.51	2.29	4.48
NA	Gini coefficient	2	36.69	5.83	32.56	40.81
	Ln(trade share of output)	2	3.85	0.84	3.26	4.45
	Ln(export share of output)	2	3.11	1.00	2.40	3.82
	Ln(import share of output)	2	3.19	0.70	2.70	3.68
SA	Gini coefficient	35	34.10	6.82	25.88	63.27
	Ln(trade share of output)	35	3.67	0.64	2.54	5.13
	Ln(export share of output)	35	2.74	0.73	1.19	4.53
	Ln(import share of output)	35	3.14	0.62	1.87	4.33
SSA	Gini coefficient	124	45.50	8.70	28.90	74.33
	Ln(trade share of output)	124	4.13	0.47	2.95	5.42
	Ln(export share of output)	124	3.21	0.59	1.92	4.58
	Ln(import share of output)	124	3.57	0.47	2.52	4.90

NOTES: Data source for all variables is WDI Database (The World Bank, 2013). The summary statistics are calculated for all the 807 observations in the dataset that have both inequality and trade data. Additional details are in Appendix A. Share of output is 100*Volume/GDP.

import share, while East Asia & Pacific (EAAP) has the highest average log of export share. For all seven regions, the log of import share has a higher average than the log of export share, while the log of export share has a higher variance than the log of import share. Given the differences, it is reasonable to expect that the effects of openness on inequality will differ across the measures.

Table 2.4: Summary Statistics: Trade Share Groups

DESCRIPTION	MEAN	S.D.	MIN.	MAX.
Gini coefficient	45.20	10.02	24.85	64.30
Ln(low trade share of output)	3.58	0.38	2.54	4.02
Gini coefficient	42.08	9.02	19.54	67.40
Ln(medium trade share of output)	4.26	0.12	4.03	4.49
Gini coefficient	40.49	10.66	19.49	74.33
Ln(high trade share of output)	4.79	0.23	4.49	5.76

NOTES: Data source for all variables is WDI Database (The World Bank, 2013). The summary statistics are calculated for all the 807 observations in the dataset that have both inequality and trade data, broken into 3 groups of openness (269 observations each). Additional details are in Appendix A. Share of output is 100*Volume/GDP.

Table 2.4 breaks down the sample of 807 observations into 3 equal groups of openness (trade share of output): low (13-55%), medium (56-89%), and high (90-317%). Gini coefficient's average falls for higher openness groups, but its variance is high for all three openness groups. It is important to next properly model the inequality-openness relationship, while controlling for other effects on inequality, to identify the effects of trade.

2.5 Results

This section presents fixed effects estimation results of the three main hypotheses and the non-linear hypothesis, as expressed in (2.1). I include regional and time fixed effects.[4] I first use the export share of output in estimating the effect of openness on inequality (*GINI*), along with control variables: income per capita (and its square) and inflation. For the third hypothesis, I present the land per capita and hydrocarbon export share results.[5]

Table 2.5 shows the results of using the export share as the openness variable. There is no evidence to support the first three hypotheses. Therefore, there is no evidence that the effect of

[4]Results are robust with the inclusion of country fixed effects.

[5]Results are insignificant with alternative endowment variables: hydrocarbon exports per capita, natural resource rents (total and per capita), capital stock per worker, and tertiary to non-tertiary education ratio.

export openness on intranational inequality is positive for all countries, positive only for more developed countries, or positive only for countries with high relative non-labor endowments. Regarding the third hypothesis, there is no evidence that the effect of the export share on inequality is conditional on the level of land per capita, as seen in specification [8]. There is some evidence contrary to the predictions of the third hypothesis, when the hydrocarbon export share is used. As specification [9] shows, the effect of the export share on inequality is positive for countries with lower hydrocarbon export shares, while it is negative for countries with higher hydrocarbon export shares. Higher export openness actually decreases inequality in more hydrocarbon-rich countries. This can be due to government's distribution of higher hydrocarbon revenue, which can result in lower inequality. Finally, the fourth hypothesis results show that the U shape effect of openness is significant, as seen in specification [10]. It follows that higher export openness decreases inequality in less open countries, while it increases inequality in more open countries. It is worthy to note that export share's turning point is roughly 48.8% of GDP (above which the effect of export share on inequality is positive), while its average effect on inequality is -0.122 (implying that at the sample's average export share of 35.9% of GDP, export share has a predicted effect of decreasing the Gini by 0.122). Throughout the regressions, the inverted-U effect of income per capita on inequality is generally significant, while inflation shows some significant positive effects on inequality. The policy implications of the export openness hypothesis test results imply that if a country is less open or more hydrocarbon-rich, then encouraging export openness would generally lower inequality.

Table 2.6 uses the import share to represent openness and shows that there is no evidence in support of any of the first three hypotheses. As with export openness, there is no evidence that the effect of import openness on intranational inequality is positive for all countries, positive only for more developed countries, or positive only for countries with high relative non-labor endowments. The results indicate evidence contrary to the predictions of the second and third hypotheses, and evidence in support of the fourth hypothesis. Namely, as specification [7] shows, the positive effect of import openness on inequality decreases with higher income per capita.

Higher import openness actually increases inequality in less developed countries, consistent with the notion that less developed countries are less able to cope with the changes brought on by higher import openness. Exposing a less developed country to many risks and changes can cause transitionary unemployment, decrease the factor returns for owners of labor, and thus cause higher inequality, as discussed by Stiglitz (2006). In relation to the HO theory, the results would imply that on average higher import openness does not raise the demand for unskilled labor in less developed (more unskilled labor abundant) countries. Furthermore, specification [9] shows that the positive effect of import openness falls with a higher hydrocarbon export share, such that higher import openness actually decreases inequality in more hydrocarbon-rich countries. Finally, as specification [10] shows, higher import openness decreases inequality in less open countries, while it increases inequality in more open countries. Import share's turning point is roughly 49.2% of GDP (slightly higher than the export share), while its average effect on inequality is -0.065 (lower magnitude than the export share). Overall, the magnitudes of the effects of the import share are generally smaller than the magnitudes of the effects of the export share, implying that inequality is less sensitive to the changes in the import share. The policy implications of the import openness hypothesis test results imply that if a country is less open, or more developed, or more hydrocarbon-rich, then encouraging import openness would generally lower inequality. Otherwise, protection policies restricting import openness would generally lower inequality.

As shown in Table 2.7, the results from using the trade share are consistent with the findings of the previous two tables.[6] Also, as specification [10] shows, trade share's turning point is roughly 94.5% of GDP, while its average effect on inequality is -0.042. Overall, given the three openness measures, there is no evidence in support of the first hypothesis, confirming the conclusions by Higgins and Williamson (2002) and E. Anderson and White (2001). This is because higher export openness can raise the relative demand for owners of unskilled labor, thus decreasing inequality. There is evidence contrary to the predictions of the second hypothesis, as similarly found by Barro (2000). This is because higher import openness can actually increase

[6]Cross-sectional estimation (without fixed effects, with robust standard errors) using the trade share for 2002 - the year with the most countries (48) - also produces significant results in support of the U hypothesis.

inequality in a less developed country if the higher openness does not raise the demand for unskilled labor (which is abundant in a less developed country). Higher import openness can create transitionary unemployment and decrease the factor returns for owners of labor, thus increasing inequality (Stiglitz, 2006). The third hypothesis results do not show evidence that the effect of openness on inequality is conditional on the level of land per capita. The results indicate some evidence that the effect of openness on inequality is conditional on the hydrocarbon export share, in a manner contrary to the predictions of the third hypothesis. Namely, higher export and import openness in a more hydrocarbon-rich country can actually decrease its inequality, since a country could have a high unskilled labor endowment and a high hydrocarbon endowment, and with greater openness the returns to unskilled labor would rise, thus decreasing inequality. There is significant evidence in support of the U shape, for all three types of openness.[7] The U shape is most pronounced with the export share, and the least pronounced with the trade share (based on the magnitudes of the effects). The underlying mechanism behind the results is that the negative effect of openness on inequality gets smaller in magnitude and then becomes positive as terms of trade start to decline and factor returns adjust. Higher export openness in a less export-open and more hydrocarbon-rich country would generate incomes and decrease inequality, which would then lead to higher imports, lower terms of trade, and higher inequality (as the country becomes more export-open and less hydrocarbon-rich). Higher import openness in a less import-open, more developed, and more hydrocarbon-rich country would encourage exports and decrease inequality, which would then lead to higher imports, lower terms of trade, and higher inequality (as the country becomes more import-open and less hydrocarbon-rich). Consistent with the earlier findings (Londoño et al., 1999; Barro, 2000; Dobson & Ramlogan, 2009), the inverted-U effect of income per capita on inequality is generally significant and robust. The average effect of income per capita is generally negative in the significant specifications for all three openness measures.

[7] Results are robust with the use of alternative inequality measures ($Q10$, $Q20$). The Gini, however, is preferable due to its comparability to the existing literature, and its ability to satisfy the inequality principles.

Table 2.5: Intranational Inequality and Export Share

ESTIMATIONS OF EQUATION (2.1)	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
HYPOTHESIS	first	second	third	third	fourth	first	second	third	third	fourth
Export share	0.021	0.037	0.029	0.015	-0.075	0.002	1.338	0.000	0.094*	-0.461**
	(0.034)	(0.138)	(0.027)	(0.011)	(0.058)	(0.074)	(1.097)	(0.057)	(0.049)	(0.199)
Ln(income per capita)	26.313***	26.033**	25.985***	32.287***	30.840***	26.837***	2.269	26.915***	34.365***	49.206***
	(5.889)	(8.246)	(6.436)	(6.804)	(7.010)	(6.230)	(22.993)	(6.672)	(4.957)	(8.741)
(Ln(income per capita))^2	-1.553***	-1.532**	-1.532***	-1.937***	-1.829***	-1.575***	0.191	-1.580***	-2.111***	-2.959***
	(0.339)	(0.519)	(0.371)	(0.404)	(0.424)	(0.357)	(1.609)	(0.383)	(0.319)	(0.543)
Ln(1+(inflation rate)/100)	1.492	1.487	1.487	4.677**	1.293	1.484*	1.078	1.485*	4.619***	0.476
	(1.087)	(1.119)	(1.089)	(1.813)	(0.957)	(0.842)	(1.314)	(0.834)	(1.471)	(0.553)
Export share * Ln(income per capita)		-0.002					-0.146			
		(0.017)					(0.114)			
Export share * Ln(land per capita)			0.002					-0.000		
			(0.007)					(0.006)		
Export share * Hydrocarbon export share				-0.001*					-0.001***	
				(0.000)					(0.000)	
(Export share)^2					0.001*					0.005**
					(0.000)					(0.002)
Constant	-69.700**	-68.804*	-68.388*	-103.038**	-86.941**	-75.347***	1.071	-75.655**	-112.064***	-156.615***
	(26.589)	(33.101)	(29.175)	(29.485)	(29.594)	(27.379)	(73.046)	(29.631)	(20.301)	(34.925)
method	OLS	OLS	OLS	OLS	OLS	IV	IV	IV	IV	IV
regional fixed effects (ρ_r)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
time fixed effects (γ_t)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
average effect of openness ($\partial Q_{it}/\partial T_{it}$ at averages)	0.021	0.022	0.022	0.013	-0.009	0.002	0.102	0.002	0.088	-0.122
average effect of income per capita ($\partial Q_{it}/\partial YPC_{it}$ at averages)	0.103	0.105	0.122	-0.410	-0.040	0.243	0.231	0.242	-1.264	-0.739
observations	803	803	803	119	803	803	803	803	119	803
Root-MSE	5.98	5.99	5.98	5.50	5.94	5.84	6.34	5.84	5.23	6.46
F statistic on $\hat{XS}_{it}$ (first stage)	-	-	-	-	-	8.97	34.08	7.82	39.75	7.77

NOTES: Estimations of equation (2.1) are done using regional and time dummies (not reported), with the Gini coefficient as the dependent variable; Export share of output is 100*Exports/GDP; Ln of income (GDP) per capita is in PPP constant 2005 international dollars; Inflation rate is annual % change in the GDP deflator; Land endowment per capita is in km^2 per person; Hydrocarbon export share is 100*(Hydrocarbon exports)/GDP; clustered (by region) standard errors are in parentheses; * p<0.1, ** p<0.05, *** p<0.01; IV regressions instrument for the export share using the predicted export share ($\hat{XS}_{it}$) from the regression below (with all the available WDI data for the three variables, from 1978 to 2010), using regional and time dummies (not reported), with robust standard errors:

$\hat{XS}_{it}$ = 96.884*** - 4.147*** Ln(population) - 3.778*** Ln(land area)   N = 5986, Root-MSE = 19.66

Table 2.6: Intranational Inequality and Import Share

ESTIMATIONS OF EQUATION (2.1)	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
HYPOTHESIS	first	second	third	third	fourth	first	second	third	third	fourth
Import share	0.031	0.202	0.039	0.015**	-0.116	0.002	0.593***	0.001	0.062**	-0.442***
	(0.032)	(0.117)	(0.027)	(0.006)	(0.086)	(0.050)	(0.205)	(0.045)	(0.028)	(0.141)
Ln(income per capita)	26.192***	25.426***	25.869***	32.041***	31.288***	26.846***	23.900***	26.889***	31.418***	43.110***
	(6.090)	(6.389)	(6.456)	(6.901)	(6.614)	(6.250)	(6.222)	(6.590)	(4.748)	(8.551)
(Ln(income per capita))^2	-1.533***	-1.432**	-1.513***	-1.916***	-1.853***	-1.575***	-1.209***	-1.578***	-1.889***	-2.593***
	(0.340)	(0.404)	(0.360)	(0.404)	(0.383)	(0.356)	(0.422)	(0.376)	(0.288)	(0.530)
Ln(1+(inflation rate)/100)	1.692	1.639	1.694	5.543**	1.292	1.498*	1.424**	1.496*	5.292***	0.580
	(1.165)	(1.121)	(1.172)	(1.649)	(1.012)	(0.780)	(0.604)	(0.782)	(0.969)	(0.561)
Import share * Ln(income per capita)		-0.020					-0.067***			
		(0.016)					(0.020)			
Import share * Ln(land per capita)			0.002					-0.000		
			(0.006)					(0.005)		
Import share * Hydrocarbon export share				-0.001**					-0.001***	
				(0.000)					(0.000)	
(Import share)^2					0.001*					0.004***
					(0.001)					(0.001)
Constant	-70.197**	-70.609**	-68.937*	-102.660**	-88.615**	-75.472***	-77.722***	-75.635**	-102.320***	-131.247***
	(28.055)	(26.355)	(29.798)	(29.876)	(29.426)	(28.550)	(23.513)	(30.033)	(20.504)	(35.649)
method	OLS	OLS	OLS	OLS	OLS	IV	IV	IV	IV	IV
regional fixed effects (ρ_r)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
time fixed effects (γ_t)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
average effect of openness ($\partial Q_{it}/\partial T_{it}$ at averages)	0.031	0.033	0.032	0.011	-0.009	0.002	0.026	0.002	0.058	-0.065
average effect of income per capita ($\partial Q_{it}/\partial YPC_{it}$ at averages)	0.308	0.423	0.334	-0.304	0.014	0.262	0.675	0.258	-0.476	-0.657
observations	803	803	803	119	803	803	803	803	119	803
Root-MSE	5.96	5.94	5.96	5.48	5.88	5.83	5.90	5.83	5.13	6.26
F statistic on $\hat{MS}_{it}$ (first stage)	-	-	-	-	-	40.64	93.44	130.25	32.83	185.17

NOTES: Estimations of equation (2.1) are done using regional and time dummies (not reported), with the Gini coefficient as the dependent variable; Import share of output is 100*Imports/GDP; Ln of income (GDP) per capita is in PPP constant 2005 international dollars; Inflation rate is annual % change in the GDP deflator; Land endowment per capita is in km^2 per person; Hydrocarbon export share is 100*(Hydrocarbon exports)/GDP; clustered (by region) standard errors are in parentheses; * p<0.1, ** p<0.05, *** p<0.01; IV regressions instrument for the import share using the predicted import share ($\hat{MS}_{it}$) from the regression below (with all the available WDI data for the three variables, from 1978 to 2010), using regional and time dummies (not reported), with robust standard errors:

$\hat{MS}_{it}$ = 111.544*** - 5.388*** Ln(population) - 4.449*** Ln(land area)   N = 5986, Root-MSE = 18.28

Table 2.7: Intranational Inequality and Trade Share

ESTIMATIONS OF EQUATION (2.1)	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
HYPOTHESIS	first	second	third	third	fourth	first	second	third	third	fourth
Trade share	0.015	0.097	0.019	0.008*	-0.044	0.001	0.406**	0.000	0.038**	-0.237**
	(0.018)	(0.075)	(0.015)	(0.004)	(0.043)	(0.030)	(0.195)	(0.025)	(0.018)	(0.095)
Ln(income per capita)	26.159***	24.256**	25.800***	32.168***	30.709***	26.840***	17.338**	26.898***	32.589***	46.241***
	(5.868)	(7.100)	(6.287)	(6.737)	(6.668)	(6.225)	(8.405)	(6.624)	(4.707)	(8.431)
(Ln(income per capita))^2	-1.539***	-1.379**	-1.517***	-1.927***	-1.824***	-1.575***	-0.782	-1.579***	-1.977***	-2.803***
	(0.333)	(0.457)	(0.357)	(0.396)	(0.402)	(0.356)	(0.603)	(0.379)	(0.292)	(0.527)
Ln(1+(inflation rate)/100)	1.588	1.551	1.586	5.128**	1.298	1.491*	1.352*	1.490*	5.020***	0.369
	(1.160)	(1.150)	(1.165)	(1.774)	(1.025)	(0.792)	(0.725)	(0.792)	(1.145)	(0.651)
Trade share * Ln(income per capita)		-0.009					-0.045**			
		(0.009)					(0.020)			
Trade share * Ln(land per capita)			0.001					-0.000		
			(0.003)					(0.003)		
Trade share * Hydrocarbon export share				-0.000**					-0.001***	
				(0.000)					(0.000)	
(Trade share)^2					0.000					0.001***
					(0.000)					(0.000)
Constant	-69.549**	-64.855*	-68.132*	-102.937**	-86.295**	-75.405***	-53.855**	-75.631**	-106.199***	-142.820***
	(26.782)	(28.384)	(28.787)	(29.283)	(28.282)	(27.962)	(27.435)	(29.828)	(19.930)	(34.227)
method	OLS	OLS	OLS	OLS	OLS	IV	IV	IV	IV	IV
regional fixed effects (ρ_r)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
time fixed effects (γ_t)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
average effect of openness ($\partial Q_{it}/\partial T_{it}$ at averages)	0.015	0.018	0.015	0.007	-0.001	0.001	0.023	0.001	0.035	-0.042
average effect of income per capita ($\partial Q_{it}/\partial YPC_{it}$ at averages)	0.174	0.253	0.198	-0.360	-0.077	0.252	0.601	0.249	-0.789	-1.071
observations	803	803	803	119	803	803	803	803	119	803
Root-MSE	5.97	5.96	5.97	5.49	5.93	5.84	5.97	5.84	5.15	6.35
F statistic on $\hat{TS}_{it}$ (first stage)	-	-	-	-	-	19.30	95.32	28.26	38.97	26.08

NOTES: Estimations of equation (2.1) are done using regional and time dummies (not reported), with the Gini coefficient as the dependent variable; Trade share of output is 100*(Exports+Imports)/GDP; Ln of income (GDP) per capita is in PPP constant 2005 international dollars; Inflation rate is annual % change in the GDP deflator; Land endowment per capita is in km^2 per person; Hydrocarbon export share is 100*(Hydrocarbon exports)/GDP; clustered (by region) standard errors are in parentheses; * p<0.1, ** p<0.05, *** p<0.01; IV regressions instrument for the trade share using the predicted trade share ($\hat{TS}_{it}$) from the regression below (with all the available WDI data for the three variables, from 1978 to 2010), using regional and time dummies (not reported), with robust standard errors:

$\hat{TS}_{it}$ = 208.427*** - 9.535*** Ln(population) - 8.227*** Ln(land area) N = 5986, Root-MSE = 35.57

The analysis contributes to the inequality-openness literature by using a larger panel dataset, testing four hypotheses, analyzing three openness measures, and accounting for the endogeneity of openness. The paper's key contributions is testing whether the effect of openness on inequality is conditional on hydrocarbon endowment and whether it is conditional on the level of openness. The paper documents evidence of higher hydrocarbon endowment putting downward pressure on the positive inequality effects of export openness and import openness. The paper shows evidence of a significant U effect of openness on inequality, revealing negative effects of export openness and import openness for lower levels of openness, and positive effects for higher levels of openness.

2.6 Conclusion

Considering all the hypotheses mentioned in this paper, and after testing them with fixed effects regressions, the results reveal a strong U shape inequality-openness relationship, for all three openness measures (export share, import share, trade share): higher openness decreases inequality in less open countries, while it increases inequality in more open countries. The turning points for the three openness measures are roughly 48.8%, 49.2%, and 94.5% of GDP respectively. The paper also finds some evidence contrary to the predictions of the second hypothesis: higher import openness increases inequality in less developed (lower income per capita) countries, while it decreases inequality in more developed (higher income per capita) countries. Contrary to the third hypothesis predictions, higher export and import openness decreases inequality in countries with higher hydrocarbon export shares. Therefore, higher export openness in a less export-open and more hydrocarbon-rich country would decrease inequality, and higher import openness in a less import-open, more developed, and more hydrocarbon-rich country would decrease inequality. Otherwise, being more open can be harmful for a country in terms of fighting its intranational inequality. Policies encouraging trade protection would then be advisable. Overall, if extreme intranational inequality is an economic illness, then the U shape inequality-openness relationship is a reminder that moderation in trade can help the economy's health.

Chapter 3

Dynamic Gravity and International Inequality

3.1 Introduction

The foundation of gravity is rooted in the field of physics. The famous Newton's Law of Gravity relates the force (F) between two masses, to their product ($m_1 m_2$), the distance between them (d), and a gravitational constant (G):

$$F = G m_1 m_2 / d^2 \tag{3.1}$$

The application of gravity to social sciences can be traced back to Carey (1865), with an analysis of migration flows. The prominence of the gravity equation within "social physics" is largely due to Stewart (1948), with an analysis of demographic gravitation. Subsequent works made significant contributions in applying the gravity equation, including J. Anderson (1979) who described frictionless gravity and a demand-side structural gravity model. The focus in this paper will be on demand-side structural gravity.[1] In the next section I review some important works in

[1]For supply-side structural gravity theory, see: Krugman (1980), Bergstrand (1985), Helpman (1987), Eaton & Kortum (2002), Melitz (2003), Chaney (2008), and Helpman, Melitz, & Rubinstein (2008).

the theory of gravity. Then I build on the model by Olivero and Yotov (2012), by expressing the *balance condition* and the *barrier-flow dynamic gravity relationship*. In this paper I aim to contribute to the existing demand-side structural gravity theory by expressing dynamic gravity and relating it to *international* inequality.

3.2 Background

J. Anderson (1979) lays out the theoretical foundations, which are also summarized in J. Anderson (2011). In a *frictionless* and *homogeneous* world, each good has the same price everywhere, and agents purchase goods in the same proportions everywhere. Consumers in country j consume country i's goods (X_{ij}), which as a fraction of country j's expenditure (E_j) equals the ratio of country i's income (Y_i) to the world income (Y). The gravity relationship for aggregated goods can thus be expressed in terms of country j's expenditure share ($b_j = E_j/Y$) and country i's market share ($s_i = Y_i/Y$):

$$X_{ij} = E_j Y_i / Y = b_j s_i Y \tag{3.2}$$

The above can also be expressed in terms of disaggregated goods, indexed by k:

$$X_{ij}^k = E_j^k Y_i^k / Y^k = b_j^k s_i^k Y^k \tag{3.3}$$

The relation in (3.2) can also be expressed in terms of bilateral shares, with $s_i^{ij} = Y_i/(Y_i + Y_j)$ representing the share of i in the joint income of i and j. Along with *balanced aggregate trade* ($b_j = s_j$), that would imply:

$$X_{ij} = s_i^{ij} s_j^{ij} \frac{(Y_i + Y_j)^2}{Y} \tag{3.4}$$

Furthermore, a measure for world openness (WO) capturing the relative amount of all exports across all countries is given by:

$$WO = \sum_j \sum_{i \neq j} X_{ij}/Y = \sum_j \sum_{i \neq j} b_j s_i = \sum_j b_j(1 - s_j) = 1 - \sum_j b_j s_j \tag{3.5}$$

Given the theoretical foundations of frictionless gravity, it is natural to then think about and model the frictions that occur in trade gravity.

Considering demand-side structural gravity, J. Anderson (1979) uses Cobb-Douglas preferences, as well as constant elasticity of substitution (CES) preferences, to derive a theoretical gravity foundation. Using both preferences, Deardorff (1998) presents a Heckscher-Ohlin model with complete specialization. J. Anderson and van Wincoop (2003), using CES preferences, present a relationship between gravity and multilateral resistance. Namely, consumers in country j maximize their utility made up of their consumption on goods from country i, denoted by C_{ij}:

$$\left(\sum_i \beta_i^{(1-\sigma)/\sigma} C_{ij}^{(\sigma-1)/\sigma} \right)^{\sigma/(\sigma-1)} \tag{3.6}$$

subject to:

$$\sum_i X_{ij} = \sum_i p_i t_{ij} C_{ij} = Y_j \tag{3.7}$$

Note that β_i is the taste parameter, $\sigma > 1$ is the elasticity of substitution, p_i is the exporter's supply price, while $t_{ij} \geq 1$ represents the trade cost factor between i and j (which is assumed to be borne by the exporter). The above maximization gives the following:

$$\frac{X_{ij}}{E_j} = \frac{X_{ij}}{Y_j} = \frac{(\beta_i p_i t_{ij})^{1-\sigma}}{\sum_i (\beta_i p_i t_{ij})^{1-\sigma}} = \left(\frac{\beta_i p_i t_{ij}}{P_j} \right)^{1-\sigma} \tag{3.8}$$

Note that $P_j^{1-\sigma} = \sum_i (\beta_i p_i t_{ij})^{1-\sigma}$, where P_j is the *inward multilateral resistance* (the buyers' incidence of trade costs). Furthermore, *market clearance* ($Y_i = \sum_j X_{ij}$) yields:

$$(\beta_i p_i)^{1-\sigma} = Y_i / \sum_j Y_j (t_{ij}/P_j)^{1-\sigma} \tag{3.9}$$

Substituting the above into the expression for X_{ij} gives:

$$X_{ij} = \frac{Y_i Y_j (t_{ij}/P_j)^{1-\sigma}}{\sum_j Y_j (t_{ij}/P_j)^{1-\sigma}} \tag{3.10}$$

Relating the above to the market share ($s_j = Y_j/Y$) yields a key expression:

$$X_{ij} = \frac{Y_i Y_j (t_{ij}/P_j)^{1-\sigma}}{Y \sum_j s_j (t_{ij}/P_j)^{1-\sigma}} = \frac{Y_i Y_j (t_{ij}/P_j)^{1-\sigma}}{Y \Pi_i^{1-\sigma}} = \left(\frac{t_{ij}}{\Pi_i P_j}\right)^{1-\sigma} \frac{Y_i Y_j}{Y} \tag{3.11}$$

Note that $\Pi_i^{1-\sigma} = \sum_j s_j (t_{ij}/P_j)^{1-\sigma}$, where Π_i is the *outward multilateral resistance* (the sellers' incidence of trade costs). Setting $p_i = 1$ in (3.8), along with (3.11) gives:

$$\beta_i^{1-\sigma} = s_i / \Pi_i^{1-\sigma} \tag{3.12}$$

Therefore, the inward multilateral resistance, referred to as the consumer price index (P_j), can be expressed in terms of the outward multilateral resistance (Π_i):

$$P_j^{1-\sigma} = \sum_i s_i (t_{ij}/\Pi_i)^{1-\sigma} \tag{3.13}$$

With a huge assumption of symmetric trade barriers ($t_{ij} = t_{ji}$), then $\Pi_i = P_i$, and the expression for X_{ij} from (3.11) becomes:

$$X_{ij} = \left(\frac{t_{ij}}{P_i P_j}\right)^{1-\sigma} \frac{Y_i Y_j}{Y} \tag{3.14}$$

The three main implications given by J. Anderson and van Wincoop (2003) are that given a uniform rise in trade barriers between all countries and assuming that each country is frictionless: (a) trade barriers reduce size-adjusted trade between large countries more than between small countries, (b) trade barriers raise size-adjusted trade within small countries more than within large countries, and (c) trade barriers raise the ratio of size-adjusted trade within country 1 relative to size-adjusted trade between countries 1 and 2 by more the smaller is country 1 and the larger is country 2.

The expression in (3.11) also gives the Constructed Trade Bias (ratio of predicted trade to predicted frictionless trade): $\left(\frac{t_{ij}}{\Pi_i P_j}\right)^{1-\sigma}$. Constructed Home Bias is thus: $\left(\frac{t_{ii}}{\Pi_i P_i}\right)^{1-\sigma}$. Using (3.11) for intranational trade, Novy (2013) expresses the product of the multilateral resistance terms:

$$\Pi_i P_i = \left(\frac{X_{ii}/Y_i}{Y_i/Y} \right)^{\frac{1}{\sigma-1}} t_{ii} \tag{3.15}$$

Expressing the above for country j as well and then combining it with (3.11) and (3.15) gives:

$$\frac{t_{ij}t_{ji}}{t_{ii}t_{jj}} = \left(\frac{X_{ij}X_{ji}}{X_{ii}X_{jj}} \right)^{\frac{1}{1-\sigma}} \tag{3.16}$$

This shows an inverse (since σ>1) relationship between relative trade barriers and relative trade flows. (Later I extend that relationship to dynamic gravity.) It also implies that higher heterogeneity (lower σ) is associated with higher relative trade barriers, for given relative trade flows. It should also be noted that with balanced aggregate trade ($b_i = s_i$) expression (3.15) implies that $\Pi_i P_i = t_{ii}$, thus making the Constructed Home Bias equal to 1.

Adding dynamics to gravity theory is useful, as trade is dynamic by nature. It also allows for estimating gravity using panel data. It can address the persistence in trade flows and trade barriers. Also, specific to the above J. Anderson and van Wincoop (2003) model, it can explore the dynamics of the multilateral resistance terms. Olivero and Yotov (2012) develop the theoretical foundations for a dynamic gravity model. They develop a theoretical general equilibrium model by incorporating the static endowment-based model of J. Anderson and van Wincoop (2003), and the dynamic two-country macroeconomic model of Backus, Kehoe, and Kydland (1994). Their resulting model is in discrete time, with a CES utility function and a Cobb-Douglas production function. The model's labor stock is assumed to be equal to 1 (across countries and time), while the capital stock follows a standard law of motion. They decompose trade flows and trade barriers into static and dynamic components, elegantly highlighting their effects on the economy.

The aim of this paper is to contribute to gravity theory in several ways. First, the paper modifies the Olivero and Yotov (2012) dynamic gravity model to include a dynamic labor stock, since population growth can affect income and inequality. Assuming a constant labor stock across all countries does not capture the varying dynamics of labor's effect on income per capita across countries. Differences in population growth rates can be an important source of inequality between countries. Then, the paper derives novel gravity expressions for income and trade flows, along with the paper's key relationships: the *balance condition* and the *barrier-flow dynamic gravity relationship*. The purpose of these expressions lies in providing a direct relationship between trade flows, trade barriers, and inequality, with mechanisms founded on the dynamic gravity model, rather than relying on the static gravity model. Ultimately, the paper describes trade flows and trade barriers, advancing their relationship to growth rates and to the *international* income per capita inequality, highlighting the various components of the inequality. The paper aims to provide a useful theoretical contribution for analyzing trade flows, trade barriers, and inequality, in the context of dynamic gravity.

3.3 Model

3.3.1 Setup

Let the consumers in country j choose their aggregate consumption (C_{jt}) out of their aggregate income (Y_{jt}). Their savings make up their aggregate investment (I_{jt}). They maximize their lifetime welfare (W_j), which depends on a time discount rate ($\rho > 0$), and constant elasticity of substitution (CES) functions of consumption (C_{jt}) and investment (I_{jt}). The CES functions differ from those in the Olivero and Yotov (2012) dynamic model, as I set the taste parameter (β_i) equal to 1, similar to the Bergstrand (1985) static model:

$$W_j = \sum_{t}^{\infty}(1+\rho)^{-t}(C_{jt}) \tag{3.17}$$

$$C_{jt} = \left(\sum_{i} C_{ijt}^{\gamma}\right)^{1/\gamma} \tag{3.18}$$

$$I_{jt} = \left(\sum_i I_{ijt}^{\gamma} \right)^{1/\gamma} \tag{3.19}$$

With $0 < \gamma < 1$, the elasticity of substitution is given by: $\sigma = 1/(1-\gamma) > 1$. Furthermore, let X_{ijt} denote country j's *nominal spending* on goods from country i, with P_{ijt} being the price of consumption goods, and Z_{ijt} being the price of investment goods:

$$X_{ijt} = P_{ijt}C_{ijt} + Z_{ijt}I_{ijt} \tag{3.20}$$

Note that $P_{ijt} = p_{it}t_{ijt}$ and $Z_{ijt} = z_{it}t_{ijt}$, where p_{it} and z_{it} denote the exporter's factory-gate prices, while $t_{ijt} \geq 1$ denotes trade barriers for shipments from i to j, which can be asymmetric ($t_{ijt} \neq t_{jit}$). For home shipments, it is assumed that $t_{iit} = t_{jjt} = 1$. In the Olivero and Yotov (2012) model, the consumption goods and investment goods are priced the same ($p_{it} = z_{it}$). For now, I can assume that as well. (Consumption goods and investment goods are priced differently in Appendix B.)

The consumer choices are bounded by constraints. Country j's aggregate nominal spending on all goods equals the aggregate income:

$$Y_{jt} = \sum_i X_{ijt} \tag{3.21}$$

The aggregate income follows a Cobb-Douglas production function. Labor (L_{jt}) and capital (K_{jt}) are used to produce a single product at price p_{jt} with $\alpha \in (0,1)$:

$$Y_{jt} = p_{jt}L_{jt}^{1-\alpha}K_{jt}^{\alpha} \tag{3.22}$$

Population growth plays a role in the dynamics of trade and inequality. Unlike the Olivero and Yotov (2012) model, I do not assume that labor is fixed at 1, but rather that labor in country j grows at rate η_{jt}:

$$L_{jt} = (1+\eta_{jt})L_{jt-1} \tag{3.23}$$

Finally, capital is the accumulation of investment and existing capital (depreciating at rate δ_j):

$$K_{jt} = I_{jt} + (1-\delta_j)K_{jt-1} \tag{3.24}$$

3.3.2 Optimality

To derive optimal conditions, consumers in country j maximize (3.17) subject to (3.18)-(3.24). This gives their nominal spending on goods from country i as the dynamic equivalent of J. Anderson and van Wincoop (2003), as in (3.8):

$$X_{ijt} = \left(\frac{P_{ijt}}{P_{jt}}\right)^{1-\sigma} Y_{jt} \tag{3.25}$$

The price index is $P_{jt} = [\sum_i P_{ijt}^{1-\sigma}]^{1/(1-\sigma)}$, while the product price is $P_{ijt} = p_{it}t_{ijt}$. Note also that the partial elasticity of relative imports with respect to variable trade barriers, given by $\frac{\partial ln(X_{ijt}/X_{jjt})}{\partial ln t_{ijt}}$, is $1-\sigma$, which Arkolakis, Costinot, and Rodríguez-Clare (2012) refer to as the trade elasticity. Furthermore, using market clearance ($\sum_j X_{ijt} = Y_{it}$) and world income ($Y_t = \sum_i Y_{it} = \sum_j Y_{jt}$), this becomes as in (3.11):

$$X_{ijt} = \left(\frac{t_{ijt}}{\Pi_{it}P_{jt}}\right)^{1-\sigma} \frac{Y_{it}Y_{jt}}{Y_t} \tag{3.26}$$

Note that $\Pi_{it}^{1-\sigma} = \sum_j (Y_{jt}/Y_t)(t_{ijt}/P_{jt})^{1-\sigma}$ and $P_{jt}^{1-\sigma} = \sum_i (Y_{it}/Y_t)(t_{ijt}/\Pi_{it})^{1-\sigma}$. Next, I can combine the economy's constraints (3.22)-(3.24) to get:

$$\left(\frac{Y_{jt}}{p_{jt}}\right)^{\frac{1}{\alpha}} = L_{jt}^{\frac{1}{\alpha}}\frac{I_{jt}}{L_{jt}} + (1-\delta_j)(1+\eta_{jt})^{\frac{1-\alpha}{\alpha}}\left(\frac{Y_{jt-1}}{p_{jt-1}}\right)^{\frac{1}{\alpha}} \tag{3.27}$$

Olivero and Yotov (2012) define real income (output) as $\frac{Y_{jt}}{p_{jt}}$. Applying their definition would then define real income per capita as $r_{jt} = \frac{Y_{jt}}{p_{jt}L_{jt}}$. Furthermore, if investment per capita is defined as $i_{jt} = \frac{I_{jt}}{L_{jt}}$, then the above relationship can be expressed as: $r_{jt}^{\frac{1}{\alpha}} = i_{jt} + (1-\delta_j)(1+\eta_{jt})^{\frac{\alpha-1}{\alpha}} r_{jt-1}^{\frac{1}{\alpha}}$. While this may be convenient, defining real income as $\frac{Y_{jt}}{p_{jt}}$ is problematic and inconsistent with the expressions in (3.20) and (3.21). Namely, consumers in country j consume goods from their own country *and* from other countries i, thus making the prices from countries i also very relevant when measuring real income. Therefore, relating nominal income (Y_{jt}) to just the home price (p_{jt}) is inconsistent. To define real income, it would be more consistent to relate the nominal income to the price index (P_{jt}), which includes the prices of *all* the goods that country j consumers buy, as in Arkolakis et al. (2012). Furthermore, Olivero and Yotov (2012) use the ratio $\frac{I_{jt}}{Y_{jt}/p_{jt}}$ in their analysis, which they define as the investment share of real output. In this paper's analysis, I can instead focus on the capital growth rate, which I can denote as $\kappa_{jt} = \frac{K_{jt}}{K_{jt-1}} - 1$.

With (3.23), (3.26) for Y_{jt-1}, and investment per capita ($i_{jt} = \frac{I_{jt}}{L_{jt}}$), then (3.27) gives:

$$Y_{jt} = \left[i_{jt}(p_{jt}L_{jt})^{\frac{1}{\alpha}} + (1-\delta_j)(1+\eta_{jt})^{\frac{1-\alpha}{\alpha}} X_{ijt-1}^{\frac{1}{\alpha}} \left(\frac{t_{ijt-1}}{\Pi_{it-1}P_{jt-1}} \right)^{\frac{\sigma-1}{\alpha}} \left(\frac{Y_{t-1}}{Y_{it-1}} \right)^{\frac{1}{\alpha}} \left(\frac{p_{jt}}{p_{jt-1}} \right)^{\frac{1}{\alpha}} \right]^{\alpha} \tag{3.28}$$

Then along with (3.22) and the capital growth rate (κ_{jt}), the above becomes:

$$Y_{jt} = (1+\eta_{jt})^{1-\alpha}(1+\kappa_{jt})^{\alpha} X_{ijt-1} \left(\frac{t_{ijt-1}}{\Pi_{it-1}P_{jt-1}} \right)^{\sigma-1} \left(\frac{Y_{t-1}}{Y_{it-1}} \right) \left(\frac{p_{jt}}{p_{jt-1}} \right) \tag{3.29}$$

Using market share ($s_{it} = \frac{Y_{it}}{Y_t}$) and home price inflation rate ($\pi_{jt} = \frac{p_{jt}}{p_{jt-1}} - 1$), country j's income becomes:

$$Y_{jt} = (1+\pi_{jt})(1+\eta_{jt})^{1-\alpha}(1+\kappa_{jt})^{\alpha} \left(\frac{X_{ijt-1}}{s_{it-1}} \right) \left(\frac{t_{ijt-1}}{\Pi_{it-1}P_{jt-1}} \right)^{\sigma-1} \tag{3.30}$$

Then using (3.23) country j's income per capita $\left(YPC_{jt} = \frac{Y_{jt}}{L_{jt}} \right)$ can be expressed as:

$$YPC_{jt} = (1+\pi_{jt}) \left(\frac{1+\kappa_{jt}}{1+\eta_{jt}} \right)^{\alpha} \left(\frac{X_{ijt-1}}{s_{it-1}L_{jt-1}} \right) \left(\frac{t_{ijt-1}}{\Pi_{it-1}P_{jt-1}} \right)^{\sigma-1} \tag{3.31}$$

Finally, plugging (3.30) into (3.26) gives the paper's *structural dynamic gravity equation*:

$$X_{ijt} = X_{ijt-1}(1+\pi_{jt})(1+\eta_{jt})^{1-\alpha}(1+\kappa_{jt})^{\alpha}\left(\frac{s_{it}}{s_{it-1}}\right)\left(\frac{t_{ijt}}{\Pi_{it}P_{jt}}\right)^{1-\sigma}\left(\frac{t_{ijt-1}}{\Pi_{it-1}P_{jt-1}}\right)^{\sigma-1} \quad (3.32)$$

The above structural dynamic gravity equation differs from the structural dynamic gravity equation of Olivero and Yotov (2012) by including population growth, and by relating current trade flows to lagged trade flows and growth rates. Specifically, it relates trade flows from country i to country j at time t to: its lag (X_{ijt-1}), trade barriers (t_{ijt}, t_{ijt-1}), multilateral resistance terms ($\Pi_{it}, P_{jt}, \Pi_{it-1}, P_{jt-1}$), exporter's market shares (s_{it}, s_{it-1}), importer's capital growth rate (κ_{jt}), labor growth rate (η_{jt}), and home price inflation rate (π_{jt}), for given $\alpha \in (0,1)$ and $\sigma > 1$.

Looking at (3.32) several observations can be made. A rise in the lagged trade flows has a positive effect on the current trade flows ($\frac{\partial X_{ijt}}{\partial X_{ijt-1}} > 0$), thus implying that habits matter. Countries that traded with each other in the previous time period are likely to continue to trade with each other. Olivero and Yotov (2012) refer to this as the *trade persistence* effect. Furthermore, trade barriers have static and dynamic effects. The static effect on trade flows is negative ($\frac{\partial X_{ijt}}{\partial t_{ijt}} < 0$), while the dynamic effect on trade flows is positive ($\frac{\partial X_{ijt}}{\partial t_{ijt-1}} > 0$). Olivero and Yotov (2012) refer to the positive dynamic effect as the *protection persistence* effect. Namely, importer's protection can lead to a higher capital formation and production, and thus create pressure for higher imports in the future. Exporter's market shares also have static and dynamic effects. The static effect of the market share on trade flows is positive ($\frac{\partial X_{ijt}}{\partial s_{it}} > 0$), while the dynamic effect on trade flows is negative ($\frac{\partial X_{ijt}}{\partial s_{it-1}} < 0$). The negative dynamic effect implies that if the exporter becomes bigger (by its market share), then there is pressure for country j to import less from country i in the future.

In terms of growth rates, importer's capital growth rate has a positive effect on trade flows ($\frac{\partial X_{ijt}}{\partial \kappa_{jt}} > 0$), which reflects low depreciation of capital relative to the new capital (investment), thus fueling higher income and consumption. Also, higher importer's labor growth rate is associated with higher trade flows ($\frac{\partial X_{ijt}}{\partial \eta_{jt}} > 0$), as higher populations consume more. This is important since population growth affects trade flows, which can affect the inequality between countries. Higher importer's home price inflation rate is also associated with higher trade flows ($\frac{\partial X_{ijt}}{\partial \pi_{jt}} > 0$). This effect of the home price can further be broken down into a positive static effect ($\frac{\partial X_{ijt}}{\partial p_{jt}} > 0$), and a negative dynamic effect ($\frac{\partial X_{ijt}}{\partial p_{jt-1}} < 0$). Thus, while home price rising increases current trade flows, it creates pressure on future trade flows to decrease.

The $\left(\frac{t_{ijt}}{\Pi_{it} P_{jt}}\right)^{1-\sigma}$ term in (3.32) represents the inverse of the trade frictions for shipments from i to j (where a higher value represents lower frictions, and thus easier trade). The growth rate of this *trade ease* is then $\xi_{ijt} = \left(\frac{t_{ijt}}{\Pi_{it} P_{jt}}\right)^{1-\sigma} \left(\frac{t_{ijt-1}}{\Pi_{it-1} P_{jt-1}}\right)^{\sigma-1} - 1$. Also, let the exporter's market share growth rate be $\mu_{it} = \frac{s_{it}}{s_{it-1}} - 1$, and let the growth rate of the trade flows be $\chi_{ijt} = \frac{X_{ijt}}{X_{ijt-1}} - 1$. Then (3.32) can be expressed in terms of growth rates:

$$(1+\chi_{ijt}) = (1+\xi_{ijt})(1+\mu_{it})(1+\pi_{jt})(1+\eta_{jt})^{1-\alpha}(1+\kappa_{jt})^{\alpha} \tag{3.33}$$

So the growth rate of trade flows is a function of the growth rates of exporter's trade ease and market share, as well as importer's home price, population, and capital.

Note that the expression for country j's income from (3.30) can be re-expressed using the aggregation of X_{ijt} from (3.32) across countries i using (3.21). This results in the following:

$$\left(\frac{X_{ijt-1}}{s_{it-1}}\right)\left(\frac{t_{ijt-1}}{\Pi_{it-1} P_{jt-1}}\right)^{\sigma-1} = \sum_i X_{ijt-1}\left(\frac{s_{it}}{s_{it-1}}\right)\left(\frac{t_{ijt}}{\Pi_{it} P_{jt}}\right)^{1-\sigma}\left(\frac{t_{ijt-1}}{\Pi_{it-1} P_{jt-1}}\right)^{\sigma-1} \tag{3.34}$$

Therefore, country j's income can be expressed as:

$$Y_{jt} = (1+\pi_{jt})(1+\eta_{jt})^{1-\alpha}(1+\kappa_{jt})^{\alpha}\sum_i X_{ijt-1}\left(\frac{s_{it}}{s_{it-1}}\right)\left(\frac{t_{ijt}}{\Pi_{it} P_{jt}}\right)^{1-\sigma}\left(\frac{t_{ijt-1}}{\Pi_{it-1} P_{jt-1}}\right)^{\sigma-1} \tag{3.35}$$

The above can also be expressed in terms of growth rates:

$$Y_{jt} = (1+\pi_{jt})(1+\eta_{jt})^{1-\alpha}(1+\kappa_{jt})^{\alpha}\sum_i X_{ijt-1}(1+\xi_{ijt})(1+\mu_{it}) \tag{3.36}$$

Using (3.23) and (3.36) gives the expression for country j's income per capita from (3.31):

$$YPC_{jt} = \left(\frac{1+\pi_{jt}}{L_{jt-1}}\right)\left(\frac{1+\kappa_{jt}}{1+\eta_{jt}}\right)^{\alpha}\sum_{i} X_{ijt-1}(1+\xi_{ijt})(1+\mu_{it}) \tag{3.37}$$

It follows from (3.22) that the summation component in (3.36) and (3.37) is equal to the lag of country j's income:

$$Y_{jt-1} = \sum_{i} X_{ijt-1}(1+\xi_{ijt})(1+\mu_{it}) \tag{3.38}$$

Therefore, income per capita can be expressed as:

$$YPC_{jt} = \sum_{i} X_{ijt}(1+\xi_{ijt+1})(1+\mu_{it+1})/L_{jt} \tag{3.39}$$

Expanding (3.38) and aggregating gives:

$$Y_{jt-1} = \sum_{i} X_{ijt-1}(1+\xi_{ijt}+\mu_{it}+\xi_{ijt}\mu_{it}) \tag{3.40}$$

$$Y_{jt-1} = \sum_{i} X_{ijt-1} + \sum_{i} X_{ijt-1}(\xi_{ijt}+\mu_{it}+\xi_{ijt}\mu_{it}) \tag{3.41}$$

Since $\sum_i X_{ijt-1} = Y_{jt-1}$ by (3.21), then (3.41) simplifies to:

$$0 = \sum_{i} X_{ijt-1}(\xi_{ijt}+\mu_{it}+\xi_{ijt}\mu_{it}) \tag{3.42}$$

This is the paper's *balance condition*, where if some country's market share is rising ($\mu_{it} > 0$) and its trade ease is rising ($\xi_{ijt} > 0$), then another country's market share and trade ease are falling. For instance, if some country is growing and it can export easier, then it is harder for another country to grow and export. This is an important relationship which highlights the interdependence of countries, and how the inequality of market shares (and therefore income) is related to the inequality of trade barriers. Thus, if the dynamics of trade barriers differ between countries, then the dynamics of market shares will react. A growth of a country's market share and trade ease puts downward pressure on the market share and trade ease of other countries. If we imagine all countries starting with symmetric trade barriers and symmetric market shares, and then trade barriers become asymmetric (causing trade ease growth rates to be different between countries), then market share growth rates will react and differ between countries, creating international inequality.

The analysis can further model the dynamics of trade flows and their relationship to trade barriers. The structural dynamic gravity equation in (3.32) can be used to find intranational trade flows (X_{iit} and X_{jjt}). Then, using the X_{iit} and X_{jjt} expressions, the intranational multilateral resistance terms ($\Pi_{it}P_{it}$ and $\Pi_{jt}P_{jt}$) can be plugged into the product of X_{ijt} and X_{jit}. This isolates the product of the trade barriers ($t_{ijt}t_{jit}$). Then, I can form the ratio of the product of the *inter*national trade barriers to the product of the *intra*national trade barriers, and relate their ratio to the ratio of the product of the *inter*national trade flows to the product of the *intra*national trade flows. The dynamic result reveals the paper's *barrier-flow dynamic gravity relationship*:

$$\frac{\left(\frac{X_{ijt}X_{jit}}{X_{iit}X_{jjt}}\right)}{\left(\frac{X_{ijt-1}X_{jit-1}}{X_{iit-1}X_{jjt-1}}\right)} = \frac{\left(\frac{t_{ijt}t_{jit}}{t_{iit}t_{jjt}}\right)^{1-\sigma}}{\left(\frac{t_{ijt-1}t_{jit-1}}{t_{iit-1}t_{jjt-1}}\right)^{1-\sigma}} \tag{3.43}$$

The term $\left(\frac{X_{ijt}X_{jit}}{X_{iit}X_{jjt}}\right)$ represents the *inter*national trade flows relative to *intra*national trade flows, while the term $\left(\frac{t_{ijt}t_{jit}}{t_{iit}t_{jjt}}\right)$ represents the *inter*national trade barriers relative to *intra*national trade barriers. The ratio of each term and its lag reflects the growth of that term. Thus, given the elasticity of substitution ($\sigma > 1$), the relationship in (3.43) shows that *the relative trade flows growth rate is inversely proportional to the relative trade barriers growth rate*. This dynamic result advances the static relationship from (3.16), which suggests an inverse relationship between relative trade flows and relative trade barriers. Through dynamic gravity, the analysis shows that the inverse relationship applies to their *growth rates*.

3.3.3 Inequality

The balance condition in (3.42) shows an underlying relationship between inequality and trade frictions. For expressing income per capita inequality, I can first use (3.31) for YPC_{it} and YPC_{jt} and denote their log difference as $Q_{ijt}^{YPC} = ln(YPC_{it}/YPC_{jt})$:

$$\begin{aligned} Q_{ijt}^{YPC} = ln\left(\frac{1+\pi_{it}}{1+\pi_{jt}}\right) + \alpha ln\left(\frac{1+\kappa_{it}}{1+\kappa_{jt}}\right) + \alpha ln\left(\frac{1+\eta_{jt}}{1+\eta_{it}}\right) + ln\left(\frac{X_{jit-1}}{X_{ijt-1}}\right) + ln\left(\frac{s_{it-1}}{s_{jt-1}}\right) \\ + ln\left(\frac{L_{jt-1}}{L_{it-1}}\right) + (\sigma-1)ln\left(\frac{t_{jit-1}}{t_{ijt-1}}\right) + (\sigma-1)ln\left(\frac{\Pi_{it-1}}{\Pi_{jt-1}}\right) + (\sigma-1)ln\left(\frac{P_{jt-1}}{P_{it-1}}\right) \end{aligned} \tag{3.44}$$

(Dividing YPC_{it} by P_{it} and YPC_{jt} by P_{jt} would give real income per capita values.) Summing the squares of the log difference gives a measure of *international income per capita inequality*, denoted as Q_t^{YPC}:

$$Q_t^{YPC} = \sum_i \sum_j (Q_{ijt}^{YPC})^2 \tag{3.45}$$

The inequality of trade barriers between trading partners can be expressed by using (3.32) to isolate t_{ijt} and t_{jit}, and then taking their log difference, denoted as $Q_{ijt}^{TB} = ln(t_{ijt}/t_{jit})$:

$$\begin{aligned} Q_{ijt}^{TB} = \frac{1}{\sigma-1} ln\left(\frac{1+\chi_{jit}}{1+\chi_{ijt}}\right) + \frac{1}{\sigma-1} ln\left(\frac{1+\pi_{jt}}{1+\pi_{it}}\right) + \frac{1-\alpha}{\sigma-1} ln\left(\frac{1+\eta_{jt}}{1+\eta_{it}}\right) \\ + \frac{\alpha}{\sigma-1} ln\left(\frac{1+\kappa_{jt}}{1+\kappa_{it}}\right) + \frac{1}{\sigma-1} ln\left(\frac{1+\mu_{it}}{1+\mu_{jt}}\right) + ln\left(\frac{\Pi_{it}P_{jt}}{\Pi_{jt}P_{it}}\right) \\ + ln\left(\frac{t_{ijt-1}}{t_{jit-1}}\right) + ln\left(\frac{\Pi_{jt-1}}{\Pi_{it-1}}\right) + ln\left(\frac{P_{it-1}}{P_{jt-1}}\right) \end{aligned} \tag{3.46}$$

Trade barriers are sometimes assumed to be symmetric ($t_{ijt} = t_{jit}$), thus making the trade barriers ratio 1, and their asymmetry (inequality) expressed by Q_{ijt}^{TB} equal to 0. That is not a very reasonable assumption, as clearly there are many reasons for the trade barriers to be asymmetric. Furthermore, the asymmetry of trade barriers is related to the asymmetries of trade flows and market shares, as inferred from (3.42), and the asymmetry of income per capita values, as inferred from (3.44). As the analysis showed earlier, a higher market share and trade ease in one country puts downward pressure on the market share and trade ease of other countries. The asymmetry of trade barriers affects the asymmetry of market shares and the international income per capita inequality. For future potential research, this interdependence and its effect on inequality can be empirically modeled to estimate the asymmetry of trade barriers. After empirical investigation, it can lead to further questions on the nature of asymmetric trade barriers, the role of trade agreements, and the implications for international trade policy.

3.4 Conclusion

In this paper I extended a dynamic gravity model introduced by Olivero and Yotov (2012). Including a dynamic labor stock, I derived optimal trade flows and their growth rates, relating them to income components and trade frictions. As a result, I derived the *balance condition* that relates trade flows to the growth rates of trade ease and market share. This novel gravity condition highlights the interdependence of countries, and how the inequality of market shares is related to the inequality of trade barriers. A growth of a country's market share and trade ease puts downward pressure on the market share and trade ease of other countries. Furthermore, in the *barrier-flow dynamic gravity relationship* I expressed relative trade flows and relative trade barriers, quantifying the ratios of the *inter*national to the *intra*national. It follows that the relative trade flows growth rate is inversely proportional to the relative trade barriers growth rate. Overall, the paper introduced international inequality within the context of dynamic gravity theory, bringing attention to the dynamics and asymmetries of trade barriers and incomes.

Appendix A

Summary Statistics: Trade Openness and Intranational Inequality

The tables presented here contain the country's average values for intranational inequality and trade openness. Intranational inequality variables include: Gini coefficient ($GINI$), income share held by the lowest 10% ($L10$), income share held by the lowest 20% ($L20$), income share held by the highest 20% ($H20$), and income share held by the highest 10% ($H10$). Trade openness variables include: trade share of output (TS), export share of output (XS), and import share of output (MS). Regarding the inequality measurement, it should be noted that: "the distributional data used here are drawn from nationally representative household surveys, which are conducted by national statistical offices or by private agencies under the supervision of government or international agencies and obtained from government statistical offices and World Bank Group country departments." (The World Bank, 2013)

Table A.1: Summary Statistics: Countries (A to F)

COUNTRY	#	*GINI*	*L*10	*L*20	*H*20	*H*10	*TS*	*XS*	*MS*
Afghanistan	1	27.82	4.08	9.40	37.48	23.21	63.22	15.57	47.65
Albania	5	31.18	3.60	8.39	39.81	24.95	66.69	20.84	45.84
Algeria	2	37.76	2.72	6.76	44.90	29.78	46.65	20.85	25.80
Angola	1	58.64	0.60	2.00	61.86	44.74	152.45	89.62	62.83
Argentina	22	48.34	1.26	3.83	52.76	35.83	28.41	15.36	13.05
Armenia	10	35.40	3.29	7.86	43.66	29.36	70.33	24.71	45.62
Australia	1	35.19	2.03	5.90	41.32	25.40	36.01	17.73	18.28
Austria	1	29.15	3.34	8.56	37.79	23.05	90.67	46.21	44.46
Azerbaijan	3	35.06	3.13	7.47	42.92	28.02	78.96	44.87	34.10
Bangladesh	8	30.19	4.09	9.23	39.75	25.55	27.35	10.25	17.10
Belarus	11	28.21	3.70	8.88	37.25	22.69	130.04	62.33	67.71
Belgium	1	32.97	3.42	8.50	41.38	28.06	153.35	78.14	75.21
Belize	7	57.58	0.93	3.01	61.32	46.74	105.29	50.71	54.58
Benin	1	38.62	3.00	6.99	46.11	31.24	40.21	13.68	26.52
Bhutan	2	42.45	2.55	6.00	49.08	33.46	89.98	39.87	50.12
Bolivia	11	56.45	0.65	2.32	59.96	43.61	57.44	27.50	29.95
Bosnia-Herzegovina	3	33.34	3.13	7.59	41.17	25.92	112.42	34.65	77.77
Botswana	2	57.59	1.36	3.37	61.95	47.06	102.75	58.81	43.95
Brazil	26	58.67	0.69	2.43	62.63	46.29	20.40	10.93	9.47
Bulgaria	8	28.45	3.50	8.71	37.36	22.93	106.52	50.74	55.78
Burkina Faso	3	45.72	2.56	5.99	52.44	38.13	36.90	11.93	24.96
Burundi	3	36.33	3.13	7.35	44.12	29.17	36.44	8.09	28.35
Cambodia	4	40.59	3.26	7.26	48.45	34.12	117.64	55.07	62.58
Cameroon	3	40.00	2.83	6.60	47.15	31.88	43.40	22.45	20.95
Canada	1	32.56	2.63	7.20	39.94	24.79	85.40	45.58	39.83
Cape Verde	1	50.52	1.88	4.54	55.90	40.64	101.09	32.54	68.54
Central African	3	53.73	1.34	3.52	58.33	42.30	33.80	11.89	21.91
Chad	1	39.78	2.61	6.26	46.56	30.79	83.38	24.63	58.75
Chile	10	54.55	1.35	3.76	59.86	44.46	61.55	32.33	29.22
China	9	34.95	3.04	7.22	42.49	26.74	37.50	19.51	17.99
Colombia	16	56.48	0.71	2.64	60.45	44.84	34.44	16.97	17.48
Comoros	1	64.30	0.91	2.55	68.02	55.19	48.09	15.11	32.98
Congo, DR	1	44.43	2.29	5.47	50.60	34.69	72.65	29.70	42.95
Congo, Republic	1	47.32	2.08	4.96	53.14	37.05	138.66	84.16	54.51
Costa Rica	23	47.06	1.15	3.91	51.78	35.15	85.76	41.18	44.58
Cote d'Ivoire	9	40.49	2.61	6.27	47.29	31.88	71.45	39.70	31.74
Croatia	6	29.93	3.64	8.64	38.79	24.13	86.35	40.26	46.09
Czech Republic	2	26.21	4.48	10.33	36.74	23.16	97.60	47.84	49.77
Denmark	1	24.70	2.62	8.34	35.80	21.28	73.80	38.73	35.06
Djibouti	1	39.96	2.42	6.03	46.47	30.91	82.32	38.57	43.75
Dominican Republic	16	49.95	1.49	4.12	55.02	39.23	71.32	32.11	39.21
Ecuador	13	53.11	0.97	3.29	57.42	41.76	61.45	29.98	31.47
Egypt	5	31.56	3.94	9.07	40.98	27.06	56.84	25.63	31.21
El Salvador	14	50.49	0.87	3.20	54.60	38.12	65.60	24.57	41.02
Estonia	7	35.74	2.85	6.97	43.08	27.71	155.15	74.32	80.83
Ethiopia	4	33.05	3.64	8.54	41.96	28.11	32.79	10.91	21.89
Fiji	2	44.82	2.08	5.16	50.59	34.80	116.40	52.72	63.69
Finland	1	26.88	4.02	9.62	36.70	22.57	78.01	43.58	34.44
France	1	32.74	2.75	7.18	40.21	25.09	44.44	22.96	21.48

NOTES: Data source for all variables is WDI Database (The World Bank, 2013). Intranational inequality variables include: Gini coefficient (*GINI*), income share held by the lowest 10% (*L*10), income share held by the lowest 20% (*L*20), income share held by the highest 20% (*H*20), and income share held by the highest 10% (*H*10). Trade openness variables include: trade share of output (*TS*), export share of output (*XS*), and import share of output (*MS*).

Table A.2: Summary Statistics: Countries (G to O)

COUNTRY	#	*GINI*	*L*10	*L*20	*H*20	*H*10	*TS*	*XS*	*MS*
Gabon	1	41.45	2.58	6.16	48.18	32.95	92.44	64.74	27.70
Gambia	2	48.76	1.79	4.41	54.05	37.56	61.37	28.20	33.17
Georgia	12	40.25	2.07	5.57	46.23	30.50	70.12	24.95	45.17
Germany	1	28.31	3.22	8.52	36.88	22.07	66.46	33.38	33.08
Ghana	5	38.60	2.55	6.29	45.33	29.66	55.17	22.24	32.93
Greece	1	34.27	2.55	6.74	41.49	26.04	65.33	25.73	39.60
Guatemala	8	56.70	0.76	2.55	60.36	44.36	54.92	21.94	32.98
Guinea	4	42.84	2.10	5.26	48.57	32.28	56.15	27.07	29.08
Guinea-Bissau	2	41.68	2.58	6.22	48.36	33.69	61.32	19.35	41.97
Guyana	2	48.05	1.46	4.38	52.79	38.39	229.23	106.66	122.57
Haiti	1	59.21	0.66	2.38	63.37	47.67	48.50	12.36	36.14
Honduras	21	56.33	0.83	2.68	60.10	43.88	101.17	44.64	56.53
Hong Kong	1	43.44	1.97	5.26	50.75	34.92	275.27	136.91	138.36
Hungary	10	26.89	4.11	9.63	36.71	22.62	118.11	58.15	59.95
India	5	32.46	3.77	8.70	41.49	27.33	20.09	9.38	10.71
Indonesia	8	30.29	4.05	9.17	39.78	25.62	53.98	28.71	25.27
Iran	5	43.28	2.16	5.38	49.26	33.41	36.37	19.10	17.27
Ireland	1	34.28	2.91	7.44	42.05	27.23	181.36	97.35	84.02
Israel	1	39.20	2.14	5.71	44.93	28.80	68.39	32.91	35.48
Italy	1	36.03	2.30	6.50	42.02	26.80	52.58	26.77	25.82
Jamaica	4	40.38	2.48	6.13	47.00	31.59	98.36	45.72	52.65
Japan	1	24.85	4.78	10.58	35.65	21.69	15.92	9.06	6.87
Jordan	7	37.38	3.12	7.23	45.09	30.08	123.51	48.46	75.05
Kazakhstan	10	33.02	3.32	7.83	41.15	25.99	88.47	46.69	41.79
Kenya	4	47.43	1.95	4.95	53.05	38.11	60.69	28.63	32.06
Korea	1	31.59	2.89	7.91	37.45	22.45	79.46	46.16	33.29
Kyrgyz Republic	9	37.91	2.90	6.83	45.21	29.66	108.86	43.75	65.10
Lao PDR	4	33.68	3.67	8.38	42.44	28.07	62.95	25.58	37.37
Latvia	10	33.70	2.88	7.38	41.39	26.46	102.29	46.88	55.41
Lesotho	4	57.41	0.88	2.48	61.28	43.86	154.59	29.32	125.28
Liberia	1	38.16	2.35	6.44	44.95	30.10	153.77	32.37	121.40
Lithuania	8	33.26	3.06	7.57	41.11	26.14	117.28	54.59	62.69
Luxembourg	1	30.76	3.50	8.43	38.85	23.77	278.99	150.00	128.99
Macedonia	9	38.71	2.38	6.08	45.18	29.40	104.58	42.95	61.63
Madagascar	6	44.78	2.26	5.52	50.86	35.78	54.45	22.05	32.40
Malawi	2	44.67	2.45	5.93	51.26	36.91	69.52	28.87	40.65
Malaysia	9	46.36	1.96	4.87	51.95	35.92	162.57	85.87	76.70
Maldives	2	50.32	1.60	4.04	55.46	38.56	150.73	78.74	72.00
Mali	3	43.19	2.42	5.76	49.60	33.87	73.92	29.47	44.46
Mauritania	6	42.01	2.25	5.71	48.24	32.87	104.66	42.35	62.31
Mexico	10	49.07	1.72	4.39	54.20	38.60	51.63	25.26	26.37
Moldova	14	36.22	2.88	6.96	43.56	28.17	126.16	47.30	78.86
Mongolia	4	33.21	3.06	7.41	40.86	25.27	107.29	48.28	59.01
Montenegro	4	30.07	3.53	8.41	38.65	23.77	121.82	41.64	80.18
Morocco	5	39.87	2.73	6.53	46.91	31.78	61.86	28.19	33.67
Mozambique	3	45.75	2.09	5.43	51.81	37.29	66.46	25.32	41.14
Namibia	2	69.12	1.00	2.32	73.44	59.88	95.24	45.86	49.39
Nepal	4	35.49	3.50	7.95	43.87	29.33	45.05	14.91	30.14
Netherlands	1	30.90	2.49	7.60	38.68	22.90	121.87	63.04	58.83
New Zealand	1	36.17	2.22	6.45	43.76	27.81	54.99	27.70	27.28
Nicaragua	4	44.80	2.17	5.34	50.73	35.36	74.12	23.75	50.37
Niger	3	40.51	2.61	6.44	47.45	32.62	39.09	16.11	22.98
Nigeria	5	44.38	1.90	4.91	49.82	33.50	68.01	37.87	30.15
Norway	1	25.79	3.86	9.59	37.23	23.38	75.96	46.54	29.43

NOTES: Data source for all variables is WDI Database (The World Bank, 2013). Intranational inequality variables include: Gini coefficient (*GINI*), income share held by the lowest 10% (*L*10), income share held by the lowest 20% (*L*20), income share held by the highest 20% (*H*20), and income share held by the highest 10% (*H*10). Trade openness variables include: trade share of output (*TS*), export share of output (*XS*), and import share of output (*MS*).

Table A.3: Summary Statistics: Countries (P to Z)

COUNTRY	#	*GINI*	*L*10	*L*20	*H*20	*H*10	*TS*	*XS*	*MS*
Pakistan	8	31.57	3.99	9.04	40.96	26.95	34.99	15.08	19.91
Panama	13	56.08	0.57	2.17	59.44	42.33	151.59	77.78	73.82
Papua New Guinea	1	50.88	1.90	4.52	56.35	40.86	107.80	59.40	48.40
Paraguay	14	53.75	0.98	3.13	57.81	41.89	100.18	47.24	52.95
Peru	16	50.25	1.42	3.89	55.00	38.86	38.84	19.70	19.13
Philippines	9	43.57	2.51	5.84	50.14	34.21	79.19	38.02	41.18
Poland	14	33.19	3.18	7.69	41.13	26.05	64.36	30.93	33.43
Portugal	1	38.45	1.99	5.76	45.87	29.84	63.66	27.76	35.90
Qatar	1	41.10	1.30	3.90	52.00	35.90	91.46	57.34	34.12
Romania	13	30.39	3.36	8.26	38.75	24.00	70.37	31.15	39.22
Russia	12	40.62	2.41	5.96	47.07	31.37	57.30	33.98	23.32
Rwanda	3	44.50	2.70	6.36	51.56	37.72	33.79	10.18	23.61
Senegal	4	44.01	2.34	5.69	50.33	35.10	65.17	27.62	37.55
Serbia	8	30.86	3.41	8.24	39.34	24.56	75.32	26.56	48.76
Seychelles	2	54.25	1.88	4.70	59.27	47.07	192.93	87.78	105.15
Sierra Leone	1	42.52	2.63	6.09	49.29	33.57	64.04	23.22	40.81
Singapore	1	42.48	1.85	5.04	48.97	32.76	316.36	169.03	147.32
Slovak Republic	9	25.82	4.23	9.99	35.99	22.20	144.11	70.25	73.86
Slovenia	5	29.74	3.66	8.67	38.53	23.81	110.76	55.30	55.45
South Africa	5	60.85	1.26	2.95	65.85	49.18	51.21	26.11	25.11
Spain	1	34.66	2.57	6.97	42.00	26.61	61.23	29.05	32.18
Sri Lanka	5	36.34	3.39	7.75	44.55	29.91	71.08	30.75	40.33
St. Lucia	1	42.58	2.01	5.23	48.34	32.48	136.86	67.55	69.31
Sudan	1	35.29	2.74	6.81	42.41	26.72	35.88	15.05	20.83
Suriname	1	52.88	1.11	3.18	56.93	40.56	60.87	27.23	33.63
Swaziland	3	54.27	1.51	3.75	58.95	43.59	146.90	66.76	80.15
Sweden	1	25.00	3.58	9.12	36.63	22.18	86.69	46.52	40.17
Switzerland	1	33.68	2.88	7.55	41.33	25.91	87.14	46.48	40.66
Syria	1	35.78	3.36	7.68	43.93	28.93	79.87	40.05	39.81
Tajikistan	5	31.72	3.22	7.94	39.94	25.05	111.55	44.36	67.19
Tanzania	3	35.34	2.97	7.19	42.92	27.75	50.21	16.68	33.53
Thailand	13	43.14	2.56	6.12	50.04	34.22	101.18	51.74	49.43
Togo	1	34.41	3.27	7.62	42.40	27.06	94.32	38.20	56.12
Trinidad-Tobago	2	41.44	1.97	5.21	46.93	30.52	74.09	40.45	33.64
Tunisia	5	41.51	2.34	5.79	47.79	32.11	86.16	41.01	45.15
Turkey	9	41.67	2.15	5.56	47.68	32.13	46.69	22.16	24.52
Turkmenistan	2	38.08	2.71	6.52	45.01	29.15	124.77	58.68	66.09
Uganda	7	42.84	2.45	5.97	49.37	34.40	38.48	13.02	25.45
Ukraine	12	29.57	3.69	8.69	38.48	23.82	96.86	48.39	48.47
United Kingdom	1	35.97	2.06	6.14	44.02	28.49	53.68	26.12	27.56
United States	1	40.81	1.88	5.44	45.82	29.85	25.95	11.04	14.90
Uruguay	18	44.81	1.79	4.80	50.23	33.76	47.01	23.34	23.66
Uzbekistan	3	38.85	2.37	6.28	45.47	30.35	57.75	30.19	27.56
Venezuela	13	48.01	1.09	3.73	52.44	35.88	50.31	29.16	21.15
Vietnam	6	36.15	3.28	7.51	44.12	28.93	123.97	57.94	66.03
Yemen	2	35.57	2.97	7.30	43.23	28.37	75.24	33.72	41.52
Zambia	6	50.55	1.55	4.00	55.39	39.41	70.81	32.87	37.94
Zimbabwe	1	50.10	1.83	4.63	55.74	40.32	79.16	38.24	40.92

NOTES: Data source for all variables is WDI Database (The World Bank, 2013). Intranational inequality variables include: Gini coefficient (*GINI*), income share held by the lowest 10% (*L*10), income share held by the lowest 20% (*L*20), income share held by the highest 20% (*H*20), and income share held by the highest 10% (*H*10). Trade openness variables include: trade share of output (*TS*), export share of output (*XS*), and import share of output (*MS*).

Below are the key variables used in the analysis, along with some additional variables that were tested during the analysis:

- *Gini coefficient* ranged from 19.49 (Slovak Republic in 1992) to 74.33 (Namibia in 1993), with an average value of 42.59 (China in 2002).
- *Trade share of output* (100*(Exports+Imports)/GDP) ranged from 12.68 (India in 1978) to 316.36 (Singapore in 1998), with an average value of 77.92 (Costa Rica in 1995).
- *Real total exports* (in PPP constant 2005 international dollars) ranged from 0.098 (Comoros in 2004) to 1989.131 (China in 2005), with an average value of 63.253 (Sweden was 63.312 in 1986).
- *Real total imports* (in PPP constant 2005 international dollars) ranged from 0.214 (Comoros in 2004) to 1692.510 (China in 2005), with an average value of 60.880 (Australia was 60.838 in 1987).
- *Real total trade* (in PPP constant 2005 international dollars) ranged from 0.312 (Comoros in 2004) to 3681.641 (China in 2005), with an average value of 124.132 (Malaysia was 124.096 in 1988).
- *Real income per capita* (in constant 2000 U.S. dollars) ranged from 95 (Congo DR in 2006) to 46458 (Luxembourg in 2000), with an average value of 3097 (Dominican Republic was 3080 in 2005).
- *Real income per capita in PPP terms* (in PPP constant 2005 international dollars) ranged from 284 (Congo DR in 2006) to 67787 (Qatar in 2007), with an average value of 6816 (Colombia in 1996).
- *Population, in thousands*, ranged from 81 (Seychelles in 2000) to 1303720 (China in 2005), with an average value of 47457 (Ukraine was 47452 in 2004).

- *Population density* (number of people per km^2 of land area) ranged from 1.48 (Mongolia in 1995) to 6176.10 (Hong Kong in 1996), with an average value of 102.50 (Indonesia was 101.76 in 1990).

- *Land area, in thousands* (in km^2), ranged from 0.30 (Maldives) to 16390 (Russia), with an average value of 1128.63 (Colombia is 1109500).

- *Investment share* (100*Investment/GDP) ranged from 4.88 (Gambia in 1998) to 66.50 (Lesotho in 1994), with an average value of 22.71 (Brazil was 22.72 in 1988).

- *Age dependency ratio* for the *young* (100*Young Population/Working-Age Population) ranged from 19.50 (Bulgaria in 2007) to 104.21 (Yemen in 1998), with an average value of 53.59 (Colombia was 53.51 in 1999), while for the *old* (100*Old Population/Working-Age Population) it ranged from 1.32 (Qatar in 2007) to 27.09 (Italy in 2000), with an average value of 11.29 (El Salvador was 11.27 in 2008).

- *Inflation rate* (annual % change in the GDP deflator) ranged from -23.48 (Ecuador in 1999) to 2735.49 (Brazil in 1990), with an average value of 37.31 (Jamaica was 37.39 in 1993).

- *Real foreign aid* (net official development assistance and official aid received, in constant 2010 U.S. dollars) ranged from 1.77 (Costa Rica in 1997) to 7964.73 (Egypt in 1991), with an average value of 587.18 (Colombia was 585.71 in 2002).

Appendix B

If Consumption Goods and Investment Goods are Priced Differently

Relating to the dynamic gravity model in Chapter 3, here I assume that consumption goods and investment goods are priced differently ($p_{it} \neq z_{it}$), to see the dynamics between the two types of consumer behavior (spending and saving). I augment the utility function (3.17) to include investment goods as well ($W = \sum_t^\infty (1+\rho)^{-t}(C_{jt} + I_{jt})$). So when consumers in country j maximize the utility subject to (3.18)-(3.24), their nominal spending on goods from country i becomes:

$$X_{ijt} = \frac{\left[(\sum_i C_{ijt}^\gamma)^{\frac{1-\gamma}{\gamma}} C_{ijt}^\gamma + (\sum_i I_{ijt}^\gamma)^{\frac{1-\gamma}{\gamma}} I_{ijt}^\gamma\right]}{(\sum_i C_{ijt}^\gamma)^{\frac{1}{\gamma}} + (\sum_i I_{ijt}^\gamma)^{\frac{1}{\gamma}}} Y_{jt} \tag{B.1}$$

I can use (3.18) and (3.19) to express the above as:

$$X_{ijt} = \left(\frac{C_{jt}}{C_{jt} + I_{jt}}\right)\left(\frac{C_{ijt}}{C_{jt}}\right)^\gamma Y_{jt} + \left(\frac{I_{jt}}{C_{jt} + I_{jt}}\right)\left(\frac{I_{ijt}}{I_{jt}}\right)^\gamma Y_{jt} \tag{B.2}$$

Note that the nominal spending is a function of fractions. Specifically, the intensity of consumption goods bought by consumers j relative to all the goods bought by consumers j can be labeled as: $\Omega_{jt} = \left(\frac{C_{jt}}{C_{jt}+I_{jt}}\right)$. Then $1 - \Omega_{jt} = \left(\frac{I_{jt}}{C_{jt}+I_{jt}}\right)$. Hence, the above becomes:

$$X_{ijt} = (\Omega_{jt})\left(\frac{C_{ijt}}{C_{jt}}\right)^{\gamma} Y_{jt} + (1-\Omega_{jt})\left(\frac{I_{ijt}}{I_{jt}}\right)^{\gamma} Y_{jt} \tag{B.3}$$

Note then that the nominal spending on consumption goods ($\sum_i P_{ijt}C_{ijt}$) is thus $(\Omega_{jt})Y_{jt}$, and the nominal spending on investment goods ($\sum_i Z_{ijt}I_{ijt}$) is thus $(1-\Omega_{jt})Y_{jt}$. Using the first order conditions, along with (3.18)-(3.21), and denoting country j's price indices as $P_{jt} = [\sum_i P_{ijt}^{1-\sigma}]^{1/(1-\sigma)}$ and $Z_{jt} = [\sum_i Z_{ijt}^{1-\sigma}]^{1/(1-\sigma)}$, the above can be expressed as:

$$X_{ijt} = (\Omega_{jt})\left(\frac{P_{ijt}}{P_{jt}}\right)^{1-\sigma} Y_{jt} + (1-\Omega_{jt})\left(\frac{Z_{ijt}}{Z_{jt}}\right)^{1-\sigma} Y_{jt} \tag{B.4}$$

Furthermore, denoting $\Pi_{it}^{1-\sigma} = \sum_j (Y_{jt}/Y_t)(t_{ijt}/P_{jt})^{1-\sigma}$, $P_{jt}^{1-\sigma} = \sum_i (Y_{it}/Y_t)(t_{ijt}/\Pi_{it})^{1-\sigma}$, $\Phi_{it}^{1-\sigma} = \sum_j (Y_{jt}/Y_t)(t_{ijt}/Z_{jt})^{1-\sigma}$, and $Z_{jt}^{1-\sigma} = \sum_i (Y_{it}/Y_t)(t_{ijt}/\Phi_{it})^{1-\sigma}$, the above becomes:

$$X_{ijt} = (\Omega_{jt})\left(\frac{t_{ijt}}{\Pi_{it}P_{jt}}\right)^{1-\sigma} \frac{Y_{it}Y_{jt}}{Y_t} + (1-\Omega_{jt})\left(\frac{t_{ijt}}{\Phi_{it}Z_{jt}}\right)^{1-\sigma} \frac{Y_{it}Y_{jt}}{Y_t} \tag{B.5}$$

Or more compactly it can be expressed as:

$$X_{ijt} = \left[(\Omega_{jt})\left(\frac{t_{ijt}}{\Pi_{it}P_{jt}}\right)^{1-\sigma} + (1-\Omega_{jt})\left(\frac{t_{ijt}}{\Phi_{it}Z_{jt}}\right)^{1-\sigma}\right] \frac{Y_{it}Y_{jt}}{Y_t} \tag{B.6}$$

Note that if $p_{it} = z_{it}$, then (B.4) becomes (3.25) and (B.6) becomes (3.26). With the economy's constraints (3.22)-(3.24) giving expression (3.27) as before (whether $p_{it} = z_{it}$ or $p_{it} \neq z_{it}$), then now with the modified expression for X_{ijt}, I can substitute for Y_{jt-1} in (3.27) using (B.6) to get:

$$Y_{jt} = \left[i_{jt}(p_{jt}L_{jt})^{\frac{1}{\alpha}} + \frac{(1-\delta_j)(1+\eta_{jt})^{\frac{1-\alpha}{\alpha}} X_{ijt-1}^{\frac{1}{\alpha}} \left(\frac{Y_{t-1}}{Y_{it-1}}\right)^{\frac{1}{\alpha}} \left(\frac{p_{jt}}{p_{jt-1}}\right)^{\frac{1}{\alpha}}}{\left[(\Omega_{jt-1})\left(\frac{t_{ijt-1}}{\Pi_{it-1}P_{jt-1}}\right)^{1-\sigma} + (1-\Omega_{jt-1})\left(\frac{t_{ijt-1}}{\Phi_{it-1}Z_{jt-1}}\right)^{1-\sigma}\right]^{\frac{1}{\alpha}}} \right]^{\alpha} \tag{B.7}$$

Then using (3.22), along with the home price inflation rate ($\pi_{jt} = \frac{p_{jt}}{p_{jt-1}} - 1$), the capital growth rate ($\kappa_{jt} = \frac{K_{jt}}{K_{jt-1}} - 1$), and the market share ($s_{it} = \frac{Y_{it}}{Y_t}$), the above becomes:

$$Y_{jt} = \frac{(1+\pi_{jt})(1+\eta_{jt})^{1-\alpha}(1+\kappa_{jt})^{\alpha}\left(\frac{X_{ijt-1}}{s_{it-1}}\right)}{(\Omega_{jt-1})\left(\frac{t_{ijt-1}}{\Pi_{it-1}P_{jt-1}}\right)^{1-\sigma}+(1-\Omega_{jt-1})\left(\frac{t_{ijt-1}}{\Phi_{it-1}Z_{jt-1}}\right)^{1-\sigma}} \tag{B.8}$$

Plugging (B.8) into (B.6) gives the paper's *structural dynamic gravity equation for* $p_{it} \neq z_{it}$:

$$X_{ijt} = \frac{\left[X_{ijt-1}(1+\pi_{jt})(1+\eta_{jt})^{1-\alpha}(1+\kappa_{jt})^{\alpha}\left(\frac{s_{it}}{s_{it-1}}\right)\right]\left[(\Omega_{jt})\left(\frac{t_{ijt}}{\Pi_{it}P_{jt}}\right)^{1-\sigma}+(1-\Omega_{jt})\left(\frac{t_{ijt}}{\Phi_{it}Z_{jt}}\right)^{1-\sigma}\right]}{(\Omega_{jt-1})\left(\frac{t_{ijt-1}}{\Pi_{it-1}P_{jt-1}}\right)^{1-\sigma}+(1-\Omega_{jt-1})\left(\frac{t_{ijt-1}}{\Phi_{it-1}Z_{jt-1}}\right)^{1-\sigma}} \tag{B.9}$$

Note that expressions (B.8) and (B.9) are generalizations and extensions when $p_{it} \neq z_{it}$, which collapse to (3.30) and (3.32) when $p_{it} = z_{it}$. Therefore, the above analysis has further advanced the dynamic gravity theory by allowing for $p_{it} \neq z_{it}$.

References

Acemoglu, D. (2002). Technical change, inequality, and the labor market. *Journal of Economic Literature*, *40*(1), 7–72.

Acemoglu, D., & Ventura, J. (2002). The world income distribution. *The Quarterly Journal of Economics*, *117*(2), 659–694.

Alesina, A., & Angeletos, G. (2005). Corruption, inequality, and fairness. *Journal of Monetary Economics*, *52*(7), 1227–1244.

Anderson, E. (2005). Openness and inequality in developing countries: A review of theory and recent evidence. *World Development*, *33*(7), 1045–1063.

Anderson, E., & White, H. (2001). Growth versus distribution: Does the pattern of growth matter? *Development Policy Review*, *19*(3), 267–289.

Anderson, J. (1979). A theoretical foundation for the gravity equation. *The American Economic Review*, *69*(1), 106–116.

Anderson, J. (2011). The gravity model. *Annual Review of Economics*, *3*, 133–160.

Anderson, J., & van Wincoop, E. (2003). Gravity with gravitas: A solution to the border puzzle. *The American Economic Review*, *93*(1), 170–192.

Angeles-Castro, G. (2011). The effect of trade and foreign direct investment on inequality: Do governance and macroeconomic stability matter? *Economía Mexicana*, *20*(1), 181–219.

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The Review of Economic Studies*, *58*(2), 277–297.

Arellano, M., & Bover, O. (1995). Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics*, *68*(1), 29–51.

Arkolakis, C., Costinot, A., & Rodríguez-Clare, A. (2012). New trade models, same old gains? *The American Economic Review*, *102*(1), 94–130.

Backus, D. K., Kehoe, P. J., & Kydland, F. E. (1994). Dynamics of the trade balance and the terms of trade: The S-curve. *The American Economic Review*, *84*(1), 84–103.

Baier, S. L., & Bergstrand, J. H. (2007). Do free trade agreements actually increase members' international trade? *Journal of International Economics*, *71*(1), 72–95.

Baldwin, R., & Taglioni, D. (2006). *Gravity for dummies and dummies for gravity equations* (Working Paper No. 12516). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w12516

Baltagi, B. H., Egger, P., & Pfaffermayr, M. (2007). Estimating models of complex FDI: Are there third-country effects? *Journal of Econometrics*, *140*(1), 260–281.

Barro, R. (2000). Inequality and growth in a panel of countries. *Journal of Economic Growth*, *5*(1), 5–32.

Becker, G. S. (1971). *The economics of discrimination.* University of Chicago Press.

Bergstrand, J. (1985). The gravity equation in international trade: Some microeconomic foundations and empirical evidence. *The Review of Economics and Statistics*, *67*(3), 474–481.

Bhagwati, J., & Srinivasan, T. (2002). Trade and poverty in the poor countries. *The American Economic Review*, *92*(2), 180–183.

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, *87*(1), 115–143.

Burtless, G. (1995). International trade and the rise in earnings inequality. *Journal of Economic Literature*, *33*(2), 800–816.

Calderón, C., & Chong, A. (2001). External sector and income inequality in interdependent economies using a dynamic panel data approach. *Economics Letters*, *71*(2), 225–231.

Carey, H. (1865). *Principles of social science*. Philadelphia: J.B. Lippincott and Company.

Center for International Development. (2001). *Research Datasets.* Retrieved from http://www.cid.harvard.edu/ciddata/geographydata.htm#general

Chen, Z. (2007). Development and inequality: Evidence from an endogenous switching regression without regime separation. *Economics Letters*, *96*(2), 269–274.

Cheng, I.-H., & Wall, H. J. (2005). Controlling for heterogeneity in gravity models of trade and integration. *Federal Reserve Bank of St. Louis Review*, *87*(1), 49–63.

Dalton, H. (1920). The measurement of the inequality of incomes. *The Economic Journal*, 348–361.

Davidson, C., Martin, L., & Matusz, S. (1999). Trade and search generated unemployment. *Journal of International Economics*, *48*(2), 271–299.

Deardorff, A. (1998). Determinants of bilateral trade: Does gravity work in a neoclassical world? In *The regionalization of the world economy* (pp. 7–32). University of Chicago.

Deininger, K., & Squire, L. (1996). A new data set measuring income inequality. *The World Bank Economic Review*, *10*(3), 565–591.

Disdier, A.-C., & Head, K. (2008). The puzzling persistence of the distance effect on bilateral trade. *The Review of Economics and Statistics*, *90*(1), 37–48.

Dobson, S., & Ramlogan, C. (2009). Is there an openness Kuznets curve? *Kyklos*, *62*(2), 226–238.

Dollar, D., & Kraay, A. (2002). Growth is good for the poor. *Journal of Economic Growth*, *7*(3), 195–225.

Dollar, D., & Kraay, A. (2004). Trade, growth, and poverty. *The Economic Journal*, *114*(493), F22–F49.

Dutt, P., & Traca, D. (2010). Corruption and bilateral trade flows: Extortion or evasion? *The Review of Economics and Statistics*, *92*(4), 843–860.

Easterly, W., & Levine, R. (2002). *It's not factor accumulation: Stylized facts and growth models* (Working Paper No. 164). Central Bank of Chile. Retrieved from http://200.10.182.196/estudios/documentos-trabajo/pdf/dtbc164.pdf

Edwards, S. (1997). Trade policy, growth, and income distribution. *The American Economic Review*, *87*(2), 205–210.

Egger, P., & Pfaffermayr, M. (2003). The proper panel econometric specification of the gravity equation: A three-way model with bilateral interaction effects. *Empirical Economics*, *28*(3), 571–580.

Egger, P., & Pfaffermayr, M. (2004). Distance, trade and FDI: a Hausman-Taylor SUR approach. *Journal of Applied Econometrics*, *19*(2), 227–246.

Feenstra, R. C., & Hanson, G. H. (1996). Foreign investment, outsourcing, and relative wages. *The political economy of trade policy: Papers in honor of Jagdish Bhagwati*, 89–127.

Feenstra, R. C., & Hanson, G. H. (1997). Foreign direct investment and relative wages: evidence from mexico's maquiladoras. *Journal of International Economics*, *42*(3), 371–393.

Feyrer, J. (2009). *Trade and income: Exploiting time series in geography* (Working Paper No. 14910). National Bureau of Economic Research. Retrieved from `http://www.nber.org/papers/w14910`

Fidrmuc, J. (2009). Gravity models in integrated panels. *Empirical Economics*, *37*(2), 435–446.

Fischer, R. (2001). The evolution of inequality after trade liberalization. *Journal of Development Economics*, *66*(2), 555–579.

Frankel, J., & Romer, D. (1999). Does trade cause growth? *The American Economic Review*, *89*(3), 379–399.

Frankel, J., & Rose, A. (2002). An estimate of the effect of common currencies on trade and income. *The Quarterly Journal of Economics*, *117*(2), 437–466.

Fujita, M., Krugman, P., & Venables, A. (1999). *The spatial economy: Cities, regions and international trade* (Vol. 213). Wiley Online Library.

Furman, J., & Stiglitz, J. E. (1998). Economic consequences of income inequality. In *Income inequality: Issues and policy options* (pp. 221–263). Symposium Sponsored by the Federal Reserve Bank of Kansas City.

Glaeser, E., Scheinkman, J., & Shleifer, A. (2003). The injustice of inequality. *Journal of Monetary*

Economics, *50*(1), 199–222.

Goldberg, P., & Pavcnik, N. (2007). Distributional effects of globalization in developing countries. *Journal of Economic Literature*, *45*(1), 39–82.

Gómez-Herrera, E. (2013). Comparing alternative methods to estimate gravity models of bilateral trade. *Empirical Economics*, *44*(3), 1087–1111.

Gourdon, J., Maystre, N., & De Melo, J. (2008). Openness, inequality and poverty: Endowments matter. *Journal of International Trade and Economic Development*, *17*(3), 343–378.

Head, K., & Mayer, T. (2015). Gravity equations: Workhorse, toolkit, and cookbook. *Handbook of International Economics*, *4*, 131–195.

Heckscher, E. F., & Ohlin, B. G. (1991). *Heckscher-Ohlin trade theory: Translated, edited, and introduced by Harry Flam and M. June Flanders*. The MIT Press.

Higgins, M., & Williamson, J. (2002). Explaining inequality the world round: Cohort size, Kuznets curves, and openness. *Southeast Asian Studies*, *40*(3), 268–302.

International Monetary Fund. (2007). *Guide on resource revenue transparency*. International Monetary Fund.

Irwin, D., & Terviö, M. (2002). Does trade raise income? evidence from the twentieth century. *Journal of International Economics*, *58*(1), 1–18.

Isard, W. (1954). Location theory and trade theory: Short-run analysis. *The Quarterly Journal of Economics*, *68*(2), 305–320.

Kuznets, S. (1955). Economic growth and income inequality. *The American Economic Review*, *45*(1), 1–28.

Leamer, E. E. (1987). Paths of development in the three-factor, n-good general equilibrium model. *The Journal of Political Economy*, *95*(5), 961–999.

Leamer, E. E. (1995). *The Heckscher-Ohlin model in theory and practice*. International Finance Section, Department of Economics, Princeton University.

Linders, G.-J. M., & de Groot, H. L. (2014). Estimation of the gravity equation in the presence of zero flows. *Econometrica*, *82*(2), 705–730.

Londoño, J., Spilimbergo, A., & Székely, M. (1999). Income distribution, factor endowments, and trade openness. *Journal of Development Economics*, *59*(1), 77–101.

Lundberg, M., & Squire, L. (2003). The simultaneous evolution of growth and inequality. *The Economic Journal*, *113*(487), 326–344.

Martin, W., & Pham, C. (2008). *Estimating the gravity model when zero trade flows are important* (Working Paper No. 9453). Munich University Library. Retrieved from http://sites.google.com/site/wmartinweb/Gravity.pdf

Martínez-Zarzoso, I. (2003). Gravity model: An application to trade between regional blocs. *Atlantic Economic Journal*, *31*(2), 174–187.

Martínez-Zarzoso, I. (2013). The log of gravity revisited. *Applied Economics*, *45*(3), 311–327.

Mátyás, L. (1997). Proper econometric specification of the gravity model. *The World Economy*, *20*(3), 363–368.

McCallum, J. (1995). National borders matter: Canada-US regional trade patterns. *The American Economic Review*, *85*(3), 615–623.

Noguer, M., & Siscart, M. (2005). Trade raises income: A precise and robust result. *Journal of International Economics*, *65*(2), 447–460.

Novy, D. (2013). Gravity redux: Measuring international trade costs with panel data. *Economic Inquiry*, *51*(1), 101–121.

Olivero, M. P., & Yotov, Y. V. (2012). Dynamic gravity: Endogenous country size and asset accumulation. *Canadian Journal of Economics*, *45*(1), 64–92.

Ondrich, J., Richardson, J. D., & Zhang, S. (2003). *The link between trade and income: Export effect, import effect, or both?* (Working Paper). Department of Economics, Syracuse University. Retrieved from http://faculty.maxwell.syr.edu/jondrich

Persson, T., & Tabellini, G. (1994). Is inequality harmful for growth? *The American Economic Review*, *84*(3), 600–621.

Rauch, J. E., & Trindade, V. (2002). Ethnic Chinese networks in international trade. *Review of Economics and Statistics*, *84*(1), 116–130.

Rodríguez, F., & Rodrik, D. (2000). Trade policy and economic growth: A skeptic's guide to the cross-national evidence. *NBER Macroeconomics Annual*, *15*, 261–325.

Rodrik, D. (1997). Has globalisation gone too far? *Institute for International Economics, Washington D.C.*.

Rose, A. K. (2004). Do we really know that the WTO increases trade? *The American Economic Review*, *94*(1), 98–114.

Rose, A. K., & van Wincoop, E. (2001). National money as a barrier to international trade: The real case for currency union. *The American Economic Review*, *91*(2), 386–390.

Sachs, J., & Shatz, H. J. (1996). U.S. trade with developing countries and wage inequality. *The American Economic Review*, *86*(2), 234–239.

Sachs, J., & Warner, A. (1995). Economic reform and the process of global integration. *Brookings papers on economic activity*, *1995*(1), 1–118.

Samuelson, P. A. (1948). International trade and the equalization of factor prices. *The Economic Journal*, *58*(230), 163–184.

Savage, I., & Deutsch, K. (1960). A statistical model of the gross analysis of transaction flows. *Econometrica*, *28*, 551–572.

Silva, J., & Tenreyro, S. (2006). The log of gravity. *The Review of Economics and Statistics*, *88*(4), 641–658.

Stewart, J. (1948). Demographic gravitation: Evidence and applications. *Sociometry*, *21*, 31–58.

Stiglitz, J. E. (2006). Social justice and global trade. *Far Eastern Economic Review*, *169*(2), 18–22.

Stiglitz, J. E. (2013). *The price of inequality: How today's divided society endangers our future*. W. W. Norton & Company.

The World Bank. (2013). *World Development Indicators.* Retrieved from `http://data.worldbank.org`

Tinbergen, J. (1962). *Shaping the world economy: Suggestions for an international economic policy*. New York: Twentieth Century Fund.

UNU-WIDER. (2008, May). *World Income Inequality Database Version 2.0c.* Retrieved from http://www.wider.unu.edu/research/database

Westerlund, J., & Wilhelmsson, F. (2011). Estimating the gravity model without gravity using panel data. *Applied Economics*, *43*(6), 641–649.

Windmeijer, F. (2005). A finite sample correction for the variance of linear efficient two-step GMM estimators. *Journal of econometrics*, *126*(1), 25–51.

Wood, A. (2002). Globalization and wage inequalities: A synthesis of three theories. *Review of World Economics*, *138*(1), 54–82.

Xu, B. (2003). Trade liberalization, wage inequality, and endogenously determined nontraded goods. *Journal of International Economics*, *60*(2), 417–431.