# Dependency Ratio and International Trade*

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**Abstract**

Does demographic structure affect trade? On one hand, a low dependency ratio in the exporting country can generate more output and hence export more. On the other hand, a low dependency ratio in the importing country can induce more labor income and hence import more. In this paper, we analyze the effect of demography on trade by augmenting the gravity equation with dependency ratio. Using a rich panel data set for 176 countries from 1970 to 2006 and controlling for multilateral resistance, we find strong empirical evidence consistent with our theoretical predictions. The finding is robust by econometric methods and by different specifications.

**JEL**: F13, P51

**Keywords**: Trade; Dependency Ratio; Gravity Equation

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# 1 Introduction

This paper investigates the impact of demographic transition on international trade. Previous works have investigated demographic transition and its impact on economic growth. In addition, there are some studies explore how trade affects economic growth. However, relatively little research has focused on the nexus between demographic transition and trade.

The world bilateral trade has increased dramatically since 1970s. As displayed in Figure 1, the average logarithm of bilateral imports increased from 6.17 in 1970 to 8.13 in 2006. That is, the average bilateral trade in 2006 has been double than that in 1970. Simultaneously, trading countries's dependency ratio, measured by dependency population over total population of a country, also experiences a 20% decrease in the last four decades, from 43.5% in 1970 to 36% in 2006. the average logarithm of working ratio, which is defined as one minus dependency ratio, increased from -.058 in 1970 to -0.45. By dividing the whole world into two groups: OECD countries and non-OECD countries, one can still observe a similar story: The average logarithm of working ratio increased from -.45 to -.39 whereas its counterpart for Non-OECD countries increased from -.62 to -.48. This raises a question: Has the fall of dependency ratio (or, the increase of working ratio) increased international trade?

[Insert Figure 1 Here]

Previous research has recognized that three factors significantly contribute to international trade: the growing GDP, the declining transportation costs, and the deepening trade liberalization (Baier and Bergstrand, 2001). A country's change of demographic structure is like changing its size of GDP. From the perspective of an exporter, with lower dependency ratio, the country has more abundant labor endowment, which in turn can generate more output and hence export more. Turning to the view of an importer, a low dependency ratio in the importing country can induce more labor income and hence is able to import more, given others constant.

This paper therefore examines the effects of trading partners' demographic transition on bilateral trade, by adopting an augmented gravity equation with dependency ratio. There are two key innovations in our theoretical gravity model. First, we introduce trading partners's dependency ratio into the model, by distinguishing the difference between total population and working labor force. Such a distinction is necessary since size of population is directly related to total consumption (demand) whereas size of labor force is directly link towards total production (supply) for a country. Second, we replace the regular economic size (*i.e.*, GDP) term with labor income in lines with Krugman (1979) and Anderson and van Wincoop(2003)'s seminal works, which in turn is decomposed into labor force and its wages return. In this way, we are able to clearly investigate the effect of trading countries' demographic dividend, which is usually used to describe a rise in the rate of economic growth due to the declining share of the age dependency ratio, on their bilateral trade volume. In addition, we also extend the country-level gravity equation to the country-industry-level gravity equation to fit with our data.

Based on the theoretical framework, we estimate the effect of dependency ratio on trade, using a rich panel data of 176 IMF-member countries over the years 1970-2006. We find robust empirical evidence that low dependency ratio (or high working ratio) significantly fosters bilateral trade, by controlling for the possible multilateral resistance issue in estimating the gravity equation. Overall, after controlling for the trading countries' fixed effects, we find that a 1% increase of working ratio for an exporter can lead to a 7.5% increase of export whereas a 1% increase of working ratio for an importer can lead to a 2.5% increase of import. Finally, we also investigate the heterogenous effect of dependency ratio across income group, consider industrial regressions, and even look at decadal estimates.

The paper joins a growing literature on trade and demography, including works done by, among others, Leff (1969), Bloom, Canning and Sevilla (2002), Bloom and Sachs

(1998), Bloom and Williamson (1998), Bosworth *et al.* (2004), and Higgins (1998). To our limited knowledge, Leff (1969) was the first seminal work to discuss how population dividend affects saving rate. Higgins (1998) took a step forward to examine the effect of demographic structure on a country's current account position by considering a dynamic link between saving rate and current account surplus. Since then, many research papers focus on how demographic structure affects the economic growth in a perspective of international comparison. For example, Bloom and Williamson (1998) found that demographic change over time plays a key role for East Asia's "economic miracle" since 1970s. In particular, one-third of the economic growth in East Asian countries is contributed by its demographic dividend. In sharp contrast, the absence of demographic change also accounts for a large portion of the economic debacle in African countries (Bloom, Canning and Sevilla 2002; and Bloom and Sachs 1998). Although the relationship between trade and economic growth has been intensively discussed in the literature of endogenous growth theory (Feenstra, 2003), only very limited works explore the nexus between demographic structure and international trade (Yao and Yu, 2009). The present paper tries to fill in this research gap in the literature.

The rest of the paper is organized as follows. Section 2 presents a theoretical gravity equation to shed line on the mechanisms by which demographic structure affects bilateral trade. Section 3 describes the data used in the paper, followed by the empirical strategy and estimation results in Section 4. Section 5 concludes the paper.

## 2 Theoretical Framework

Following Yu (2010, 2011), suppose that each country produces unique product varieties. Let $h$ represent the good, $k$ represent the industry, $i$ represent the exporter and $j$ represent the importer. The export of good $h$ in industry $k$ from country $i$ to country $j$ is identical to the consumption of good $h$ in industry $k$ in the Importer. Exporter $i = 1, ..., I$ has $K$ industries. Industry $k \epsilon K$ produces $M_k^i$ commodities. Then, the exporter faces an aggregate CES utility function:

$$U = \int_{i=1}^{I}\int_{k=1}^{K}\int_{h=1}^{M_k^i}(C_{i,j,k}^h)^\rho dhdkdi, (\rho > 0) \tag{1}$$

where $C_{i,j,k}^h$ is the importer $j$'s consumption of good $h$ in industry $k$ produced by country i. The elasticity of substitution $\sigma$ is denoted as $\sigma = 1/(1-\rho)$.

We follow Anderson and van Wincoop (2003) to assume that, given each exporter $i$, $p_{i,j,k}^h = p_{i,j,k}^{h'}$ for all $h$ and $h'$ in $\{1, ..., N_{ik}\}$, *i.e.*, all the goods in industry $k$ imported by country $j$ from country $i$ have the same price $p_{i,j,k}$. In addition, country $j$'s consumption is identical over the entire line of products within industry $k$ sold by country $i$, *i.e.*,

$C_{i,j,k}^h = C_{i,j,k}^{h'} = C_{i,j,k}, \forall h \in \{1, ...M_k^i\}$. Utility function (1) can then be expressed as:

$$U = \int_{i=1}^{I}\int_{k=1}^{K} M_k^i (C_{i,j,k})^\rho dkdi. \tag{2}$$

The representative consumer in the country $j$ maximizes her utility (2) subject to the budget constraint:

$$Y^j = \int_{i=1}^{I}\int_{k=1}^{K} M_k^i p_{i,j,k} C_{i,us,k} dkdi, \tag{3}$$

where $Y^j$ is the GDP of country $j$. By solving this maximization problem, we obtain the demand function for each product:

$$C_{i,j,k} = (p_{i,j,k}/P_{j,k})^{\frac{1}{\rho-1}}(Y^j/P_{j,k}), \tag{4}$$

where the aggregate price index of country $j$, $P_{j,k}$, is defined as:

$$P_{j,k} \equiv [\int_{i=1}^{I}\int_{k=1}^{K} M_k^i (p_{i,j,k})^{\frac{\rho}{\rho-1}} dkdi]^{\frac{\rho-1}{\rho}}. \tag{5}$$

Hence, the total value of country $j$'s imports from country $i$ in industry $k$ is:

$$X_{j,k}^i \equiv \int_{h=1}^{M_k^i} p_{i,j,k}^h C_{i,j,k}^h dh = M_k^i p_{i,j,k} C_{i,j,k}, \tag{6}$$

where the first equality follows the definition of export value, and the second one is due to the equal price assumption across varieties of goods.

In spired by Samuelson (1952), the "iceberg" transport cost introduces a wedge between a *c.i.f* (customs, insurance, and freight) price, $p_{i,j,k}$, and *f.o.b* (free on board) price, $p_{i,k}$. In the present paper the trade cost is not the main interest but only serves as a control variable here. Hence we follow Eaton and Kortum (2002) to use geographic distance ($d_{ij}$) to capture the transport cost. In particular,

$$p_{i,j,k} = d_{i,j} p_{i,k}, \tag{7}$$

where the regular triangle property holds: $d_{i,n} d_{nj} > d_{i,j} > 1$ and $d_{i,i} = 1, \forall i, j, n$. Combining (4), (5), and (6), we obtain the export value of industry $k$ from country $i$ to country $j$:

$$X^i_{j,k} = M^i_k Y^j (d_{i,j} p_{i,k} / P_{j,k})^{\frac{\rho}{1-\rho}}. \tag{8}$$

However, bilateral trade is also affected by the number of varieties in the exporting country, $M^j_k$, which is unfortunately unobservable. For estimation, we consider the monopolistic competition model presented originally by Krugman (1979), which helps us to eliminate the number of exporting varieties in our gravity equation (8).

Turning to the supply side, the representative firm in a country maximizes profits. Specifically, as in Krugman (1979), Baier and Bergstrand (2001), and Feenstra (2002), the production of goods ($y^i_k$) incurs a fixed cost ($\kappa^i_k$) and a constant marginal cost ($\phi^i_k$) given that labor ($l^i_k$) is the representative firm's unique input in industry $k$ of country $i$:

$$l^i_k = \kappa^i_k + \phi^i_k y^i_k. \tag{9}$$

The monopolistically competitive equilibrium implies two conditions for the representative firm. First, the marginal revenue should equal marginal cost for the representative firm. Since the elasticity of demand equals the elasticity of substitution, $\sigma$, when the exporter's number of goods $M^j_k$ is large, We obtain the first equilibrium condition:

$$\rho p^i_k = \phi^i_k w^i, \tag{10}$$

where the wage in Country $i$ is denoted as $w^i$. From the equation above, we could find that wage captures the exporting country's labor productivity, because it is determined by product price and marginal production.

Second, the representative firm obtains zero profits due to free entry. Given that the firm's profit function in the country $i$ is $\pi_k^i = p_k^i y_k^i - w^i(\kappa_k^i + \phi_k^i y_k^i)$, we obtain the equilibrium production level, $\bar{y}_k^i$, for such a representative firm in industry $k$ in Country $i$:

$$\bar{y}_k^i = \frac{\rho \kappa_k^i}{(1-\rho)\phi_k^i}.$$

It is also noted the GDP in country $i$ is $Y^i = M_k^i p_{ik} \bar{y}_k^i / s_{ik}$ where $s_{ik}$ is output share of industry $k$ in Country $i$. Then, the industry-level bilateral trade equation becomes:

$$X_{j,k}^i = \frac{s_k^i Y^i Y^j}{(p_{ik})\bar{y}_k^i}(d_{i,j} p_{ik}/P_{j,k})^{\frac{\rho}{1-\rho}}. \tag{11}$$

It is worthwhile to point out that the GDP is merely the labor income in the model: $Y^n = w_n L_n, \forall n = i, j$, where $L$ is number of labor force. As stated in the introduction, countries who are experiencing the second stage of demographic transition would enjoy the benefits of "demographic dividend". These countries have low dependency ratios which mean relatively high level of labor supply. On the other hand, the countries with high dependency ratio have relatively low level of labor supply. Thus, we embed dependency ratio, a variable of age structure, in the theoretical model. To match the definition in the World Development Indicator (WDI) data base, we define a country's dependency ratio as $\lambda_n = (N^n - L^n)/N^n$ where $N^n$ is the total population of country $n$.[1] Then from (11) we obtain the following industry-level bilateral trade equation:

$$X_{j,k}^i = \frac{s_k^i w^i N^i w^j N^j (1-\lambda_i)(1-\lambda_j)}{p_{ik}\bar{y}_k^i}(d_{i,j} p_{i,k}/P_{j,k})^{\frac{\rho}{1-\rho}}. \tag{12}$$

[1]Note that our theoretical prediction and empirical findings do not change by using an alternative index of dependency ratio $(N^n - L^n)/L^n$.

Therefore, the industry-level bilateral trade depends on the dependency ratio as well as the trading countries' wages, numbers of population, exporter's industrial output share, the fixed production of China's representative firm, and various price indices. Different from the standard gravity equation, our revised gravity equation do not include GDP but decompose it to labor return, number of population, and dependency ratio for our estimation purpose. For convenience, I include the main notation of the model in Appendix Table 1.

To estimate the gravity equation (12), we specify the estimating equation by taking logs on both sides:

$$\begin{aligned} \ln X^i_{j,k} \;=\; & \ln w^i + \ln w^j + \ln N^i + \ln N^j + \ln(1-\lambda_i) - \ln(1-\lambda_j) + \frac{\rho}{1-\rho}\ln d_{i,j} \quad (13) \\ & +[\ln s^i_k - \ln \bar{y}^i_k + \frac{1}{1-\rho}\ln p_{i,k} + \frac{\rho}{\rho-1}\ln P_{j,k}] \end{aligned}$$

However, in (13), both the representative firm's production ($\ln \bar{y}^i_k$) and the industrial output share ($\ln s^i_k$) in the exporting country are all unobservable. In addition, data on the industrial price index for both exporter and importers are also unavailable, we therefore capture all these terms into the error term following Feenstra (2002):

$$e^i_{jkt} = \ln s^i_k - \ln \bar{y}^i_k + \frac{1}{1-\rho}\ln p_{i,k} + \frac{\rho}{\rho-1}\ln P_{j,k}.$$

Thus, we have the following specification for the estimations:

$$\ln X^i_{j,k} \;=\; \beta_0 + \beta_1 \ln w^i + \beta_2 \ln w^j + \beta_3 \ln N^i + \beta_4 \ln N^j \quad (14)$$

$$+\beta_5 \ln(1-\lambda_i) + \beta_6 \ln(1-\lambda_j) + \beta_7 \ln d_{i,j} + e^i_{jkt} \quad (15)$$

Note that in this bilateral trade equation (14) we do not restrict the coefficient of trading partners' dependency ratio as a unit. Instead, the coefficients $\beta_5$ and $\beta_6$ are allowed to absorb the effects of demographic structure on bilateral trade in a flexible manner.

## 3 Data

The regressand of (14) is the log industrial directional import of country $j$ from country $i$. Note that the gravity theory merely mentions that the gravity equation explains one-way trade flows (*e.g.*, Chinese exports to the U.S.) rather than the two-way bilateral trade (*e.g.*, Chinese exports to the U.S. and the U.S. exports to China). Accordingly, ignoring this difference can create serious estimation bias (Baldwin and Taglioni, 2006).

All data used in the present paper are publicly available. The nominal directional import data are compiled from two sources: data before 2002 the NBER-UN Trade data maintained by Feenstra *et al.* (2005) whereas data after 2002 are from the COMTRADE directly. Since such nominal data are recorded in American dollars, we deflate them by the American CPI (1995=100) to obtain the real value following Rose (2004). We first use country-level aggregated trade data to check the overall effect of dependency ratio on trade, followed by the country-industry level disaggregated trade data to consider for the industrial heterogeneity. In particular, we obtain 558,838 observations for 176 countries over the years 1970-2006 by choosing SITC 1-digit level directional import data for regressions.[2]

[Insert Table 1 Here]

Information related to number of population and dependency ratio are directly from the World Development Indicator (WDI, 2010) of the World Bank. The geographic distance between trading countries is adopted from Rose (2004). Unfortunately, data on the price levels of trading partners are unavailable at the industrial level. Therefore, we have to use the consumer price index (CPI) in both trading countries to measure the exporter $i$'s price level $p_i$ following Baier and Bergstrand (2001). Data on the price index specify the base year as 1995 and can be accessed from WDI (2010) again. The wage data are also from WDI (2010) which are measured by workers' remittances and compensation of employees

[2] Although bilateral trade data is available as early as 1962, the wage data is unavailable until 1970.

dividend by working population in a country. To measure labor return at the industrial level, we also adopt an alternative wage data set which covered years from 1983 to 2003 and are maintained by the Bureau of Labor Statistics.

[Insert Figure 2 Here]

Panel A of Table 1 presents descriptive statistics for each variable. As also observed from Figure 2A, the variation of dependency ratio of trading countries seems relatively low due, in large part, to the low variation within the high-income country group over time. To shed light on this point, Figure 2B and 2C describe the kernel density function of dependency ratio for both OECD countries and Non-OECD countries, respectively.[3] At first glance, all figures in Figure 2 have a well-behaved shape of distribution. More importantly, Non-OECD countries on average have a wider dispersion than that in OECD countries. Turning to the relationship between dependency ratios and log of bilateral trade, Panel B of Table 1 reports their simple correlations. In particular, the simple correlation between dependency ratio of exporter (importer) and log of bilateral trade is -.274 (-.223). Figure 3A and 3B plot the log of bilateral trade against log of working ratio for importer and exporter, respectively. Clearly, countries with lower dependency ratio (or higher working ratio) trade more with its trading partners, regardless of exporter and importer.

[Insert Figure 3 Here]

# 4 Estimates

It has been recognized that various trade costs play an important role for bilateral trade volume (Anderson and van Wincoop, 2004). Longer distance costs and other border effects

[3] The Organization of Economic Cooperation and Development countries including the following 27 countries: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxemburg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, and the United States.

can significantly reduce bilateral trade economically and statistically significantly. One may worry that a country's dependency ratio may only pick up the effects from trade-cost variables like geographical distance. To check for this, Our first estimate is to compare the OLS estimates *without* and *with* variables of trading countries' working ratios. As shown in Column (1) and (2) of Table 2, the trade-cost variable (*i.e.*, log of geographic distance) are insensitive between the two estimates in terms of signs and economic magnitudes. Note that including more standard trade-cost variables such as land border, number of island or other regional trade agreement variables like WTO membership, number of free trade agreements (FTA), Currency unions, and/or Generalized System of Preferences (GSP) do not change this finding.[4]

[Insert Table 2 Here]

As shown in (13), the bilateral trade volume also depends on the price index for both exporter and importer. Although data on the industrial price index are unavailable, it is still worthwhile to use country-level CPI to serve as a price proxy. Column (3) of Table 2 runs the OLS estimate by including log of CPI for both exporter and imports. The coefficients of working ratio for both trading countries again are positively associated with bilateral trade, inclusive of price index.[5] The economic rationale is as follows, with a high working ratio, the exporter can produce more products, which in turn could export more goods abroad, *ceteris paribus*.

## 4.1 Control of Multilateral Resistance

In addition to the variables included in (13), different trading country pairs could have unobserved specific country characteristics, which can be addressed by the fixed effects estimations. Hence, the error term in (14) can be decomposed into a country-pair random

[4]We do not report estimates with such additional variables here to save space, though available upon request.

[5]Using the producer price index (PPI) or wholesale price index (WPI) does not change the results at all.

variable $\varphi_{ij}$, an industry specific effect $\lambda_k$, a year specific effect $\omega_t$, and an idiosyncratic effect $\epsilon_{ijkt}$ with normal distribution: $\epsilon_{ijkt} \sim N(0, \sigma^2_{ijk})$. This is represented as follows:

$$e_{ijkt} = \varphi_{ij} + \lambda_k + \omega_t + \epsilon_{ijkt}. \tag{16}$$

Column (4) of Table 2 presents the two-way fixed-effect estimation results. Once again, the variables of working ratio for exporters and importers have positive signs, which are all statistically significant at the conventional level. In particular, given others constant, an 1% increase of exporter's working ratio tend to have 7.5% increase of bilateral trade. Similarly, an 1% increase of importer's working ratio tend to have 2.5% increase of bilateral trade.

Moreover, note that the importer's aggregate price index in (13), which is absorbed into the error term, is also affected the price of goods from other countries. Therefore, it is essential to control for such a "multilateral resistance" mentioned by Anderson and van Wincoop (2003) in order to precisely estimate the gravity model. Following Baldwin and Taglioni (2006), we perform the time-varying country fixed effects by including 2*N*T more dummy variables, where N is the number of countries and T is the number of years. These dummy variables include N*T variables to indicate a pair of exporter-year and another N*T variables to indicate another pair of importer-year. The inclusion of these dummies allows us to control for the possible variances related to other trading countries in the world, and accordingly release the multilateral resistance effect. The fixed-effects estimates with the control of multilateral resistance, as shown in Column (5) of Table 2, are again positive and highly significant at the conventional statistical level.

### 4.2 Zero Trade Issue

Recent researches like Westerlund and Wilhelmsson (2006), Santos Silva and Tenreyro (2006), and Helpman *et al.* (2007) have pointed out that the gravity equation with a log-linearization form may cause some estimation bias due to the zero trade issue: the entire portion of the observations with zero trade volume have to be dropped when taking the log-linearization to estimate bilateral trade volume. Santos Silva and Tenreyro (2006) show that a truncated Poisson pseudo-maximum Likelihood (PPML) approach is an appropriate method to deal with the zero trade volume.[6] We therefore perform the PPML estimates by directly taking the bilateral trade volume as regressand. As shown in the last column of Table 2, after controlling for the country-pair-specific fixed effects and year-specific fixed effects, the PPML estimates end up with a similar result as in Column (4) in which a linear-logarization of gravity equation is adopted. The working ratios of both importer and exporter are positively associated with bilateral trade.

### 4.3 Further Estimates on Sectoral Heterogeneity

As predicted by the Rybczynski (1955) theorem of the standard Heckscher-Ohlin trade theory, different industries would have heterogenous effects on its production in response to the changing working labor endowment. In particular, in a two-good and two-factor model, an increase in the amount of working labor will raise the output of the industry using it intensively, and lower the output of the other industry. To capture the effect of demographic structures on industrial trade volume between the trading partners, we take a step further to measure bilateral trade volume at SITC 1-digit industry level, by aggregating the SITC 4-digit level trade data from the COMTRADE database.

Table 3 presents the industrial estimation results. By including industrial trade data, the estimates in Table 3 have much more observations than those in Table 2, yet their estimation results are quite close. The benchmark OLS estimate in Column (1) once again suggests that working ratios in both trading countries are associated with more bilateral trade. Different from its counterpart in Table 2, the fixed-effects estimates in Columns (2)-(3) include the industrial-specific fixed effects but still get similar estimation results. Like before, we also include the time-varying country fixed effects in Column (3) to control for

[6] The revised Heckman two-step approach is another useful way to address the zero trade issue. Using this alternative approach can generate similar results, which do not report in the text to save space though available upon request.

the multilateral resistance whereas perform the PPML estimate in the last column of table 3 to control for the zero trade issue. It turns out that all the specifications in Table 3 are very insensitive and consistent with our theoretical prediction: The less the dependency ratios or the more the working ratios in the trading countries, the higher the bilateral trade.

[Insert Table 3 Here]

### 4.4 Additional Robustness Estimates

In the previous estimates, wages data are from the WDI database which is measured by workers' remittances and compensation of employees dividend by working population in a country. The advantage of using such wages data is that it covers longer periods and more countries. However, such data are at highly aggregated country-level. In the reality, wages in different industries would be quite different. As a result, once can not explore the industrial effect of labor income on bilateral trade.

To overcome this data challenge, we adopt another wage dataset which is from the Bureau of Labor Statistics (BLS) as a robustness check. The BLS wage data cover only OECD countries during 1983-2008 but have full information on industrial wage.[7] By using such BLS wage data, In Table 4 we run a variety of specifications including OLS, fixed effects, and PPML estimations at the industrial level. Overall, the findings are insensitive to our previous findings.

[Insert Table 4 Here]

### 4.5 Endogeneity Issues

The main aim of our theoretical model is to shed light on the channels that demographic structures in trading countries affect bilateral trade. There still exist some other variables

[7] The BLS industrial wages are based on its own classification. We then construct the SITC 1-digit level wages by using a concordance between SITC and the BLS industrial classifications, which is available upon request.

that are abstracted away from our current theoretical framework. Such omitted variables may not be completely absorbed by the country–pair-specific and year-specific fixed effects or time-varying country fixed effects. In this way, the omitted variables problem would generate a possible endogeneity issue to make the previous OLS estimates bias.[8]

We hence choose a country's life expectancy to serve as an instrument variable to control for the possible endogeneity issues. People in a country with longer life expectancy may work longer in their life time, which in turn introduce a higher working ratio (*i.e.*, lower dependency ratio). To test whether a country's life expectancy satisfies the "exclusive restriction", that is, the instrument affects the regressand through and only through the endogenous variable, we follow previous works in running regressions of instruments on the residual obtained in the second-stage estimations. It turns out that the coefficient of this instrument is highly insignificant which, to some extent, excludes other possible channels.

We then perform more tests to check for the validity of the instrument. In particular, we use the Kleibergen-Paap (2006) LM $\chi^2$ statistic to check whether the instruments are correlated with the endogenous variables. As shown in Table 5, the null hypothesis that the model is under-identified is rejected at the 1% significant level. Second, the Kleibergen-Paap (2006) F statistic provides strong evidence to reject the null hypothesis that the first stage is weakly identified at a highly significance level. Finally, the first-stage estimation results shown in the lower module of Table 5 also provide strong evidence to justify the validity of such instruments. Both the t-value of the instrumental variable and the overall F-statistic are highly significant at the conventional level for all specifications. In short, such various statistical tests offer sufficient confidence that the instrument are "relevant"

[8] Another possible source of endogeneity issue comes from the reverse causality. With more trade, the idea and ideology may spillover from a country to its trading partner, which would in turn change people's view on fertility decision and hence affect a country's dependency ratio in the long run. Admittedly it is not sure how important for the reverse causality in our estimations. However, the endogeneity bias caused by such a reverse causality, if any, could be mitigated by the instrumental-varaible estimate that we will mention shortly.

and perform quite well, and therefore, that the specification is well justified.

Table 5 presents the IV estimation results. In column (1) we only include the two key variables, log of working ratio for both exporter and importer, in the regression. The estimation result from this simple specification clearly conveys a message that higher working ratios of trading countries lead to larger bilateral trade volume. We then provide a variety of more matured specifications in the rest of Table 5 and still have very robust findings. In particular, by including year-specific fixed effects in Column (2), country-pair-specific and year-specific fixed effects in Column (3), and time-varying country-specific and year-specific fixed effects in Column (4) to control for the multilateral resistance, the coefficients of log of working ratios for both exporter and importer are positive and statistically significant.

[Insert Table 5 Here]

### 4.6 Additional Estimates by Country Group

As discussed above and shown in Figure 3, the dependency ratios in developed countries (DCs), overall, are less violatile over years. The estimates with the pooling data may under-estimate the effect of dependency ratio/working ratio on bilateral trade for less developed countries (LDCs) whereas over-estimate such an effect for developed countries. To avoid such possible bias, Table 6 reports the fixed-effects estimates by trade origin and destination, by separating all countries to the two groups: developed countries and less developed countries by using the World Bank's classification.[9]

As shown in Table 6, the coefficients of log of working ratio of importer are positive and statistically significant in all columns except the Column (4), which has a negative sign but is statistically insignificant. This suggests that, the lower dependency ratio (or the higher working ratio) suggests more labor income, which in turn generates a strong demand from

[9] According to the World Bank (2009)'s classification, a country which gross national income (GNI) is higher than $ 12,196 is classified as a developed country.

the rest of the world. Turning to the exporter's side, the coefficients of working ratios of LDCs exporters are all positive and statistically significant. In contrast, the coefficient of working ratios of DCs exporters are positive but insignificant (*i.e.*, exports from DCs to DCs) or negative and significant (*i.e.*, exports from DCs to LDCs). Such striking findings are due, in part, to the less variation of dependency ratio for rich exporters. Nevertheless, all other variables have the predicted positive signs and quite stable magnitudes.

[Insert Table 6 Here]

### 4.7 Decadal Fixed Effects Estimates

Once again, to precisely estimate the gravity equation with dependency ratio, it is a key to control for the multilateral resistance effects involved in the gravity equation, which has been controlled by the time-varying country fixed effects and year-specific fixed effects. However, one may still worry about the multilateral resistance could diverge (or converge) in the last four decades. To address such a concern, we therefore divide the whole sample into four sub-samples and run the decadal estimates in Table 7. For each decadal estimates, the estimation results are very robust to different econometric methods including OLS, fixed effects, IV fixed effects, and even the PPML estimates. The coefficients of the two key variables, log of working ratios for both exporter and importers are positive and statistically highly significant. In addition, they all have quite stable magnitudes over year and across specifications. These serve as another set of evidence that higher dependency ratio leads to less bilateral trade.

[Insert Table 7 Here]

## 5 Concluding Remarks

In this paper, we argue that dependency ratio is a key driving force for bilateral trade growth. An exporter with low dependency ratio or high working ratio would be relatively more labor abundant compared to its trading partner, which in turn produce and export more products. Turning to the importer's side, a country with more labor endowment would generate more labor income and hence be able to import more.

To formalize this idea we extend the general-equilibrium gravity model originally from Anderson and van Wincoop (2003) by embedding trading countries' dependency ratio in the model. Guided by such a theoretically-grounded gravity equation, we are able to estimate the effect of dependency ratios (or equivalently, working ratios) on bilateral trade by using a rich panel data set. We find robust evidence that trading partners' low dependency ratios lead to high bilateral trade volume, which is consistent with our theoretical prediction. Such findings are robust, by controlling for the possible endogeneity issue and even the multilateral resistance which occurred in the bilateral trade gravity estimation, and by allowing a variety of different econometric specifications.

The paper enriches our understanding between demography and trade. Previous works like Lee (2003) have recognized that demographic transition plays a vital role on economic growth. The other branch of literature like Grossman and Helpman (1991) also work intensively on the endogenous nexus between trade and growth. However, to the best of our knowledge, the present paper is the first one to deliver a theoretical framework to explore how demographic transition affects international trade.

Our paper also have rich policy implications. Today many emerging countries like China and other East Asian countries enjoy the fast economic growth due, in large part, to the adoption of "export-led" economic strategy, focusing on labor intensive industries in line with their comparative advantage. In this paper we argue that demographic transition is a key reason to interpret these countries' choices of the export-oriented development strategy, rooted in a common demographic characteristics with large amount of surplus labor, which consequently leads to an excess domestic supply in labor-intensive sector. In this sense, as initiated by Lin (2009), the choice of "export-led" development strategy chosen by such high-performance countries, to some extents, are endogenous and selfselected.

Several extensions and possible generalizations merit special consideration. One of them is to consider a dynamic theoretical framework in the model. Like all kinds of gravity model, our model in essence is static. Therefore, a possible extension with dynamic structure would be a direction for future work. Another possible extension is to deviate away from the standard assumption by allowing trade imbalance in the model, which could be more close to the reality. These are the topics that we will pursue in the future.

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Table 1: Basic Information

Panel A: Summary Statistics

| Variable | Mean | Std. Dev. |
|---|---|---|
| Bilateral trade | 7.90 | 3.46 |
| Log of Dependency Ratio of Exporter | .342 | .046 |
| Log of Dependency Ratio of Importer | .343 | .046 |
| Log of Distance | 8.15 | .812 |
| Log of Labor Income of Exporter | 14.1 | 2.37 |
| Log of Labor Income of Importer | 14.0 | 2.36 |
| CPI of Exporter | 29.3 | 252 |
| CPI of Importer | 28.5 | 249 |

Panel B: Simple Correlation

| Correlation | Log of Bilateral Trade | Dependency Ratio of Exporter | Dependency Ratio of Importer |
|---|---|---|---|
| Log of Bilateral Trade | 1.00 | | |
| Dependency Ratio of Exporter | -.274 | 1.00 | |
| Dependency Ratio of Importer | -.223 | -.049 | 1.00 |

Table 2: Benchmark Country-Level Estimations

| Method | OLS | | | FE | | PPML |
|---|---|---|---|---|---|---|
| Regressand: | (1) | (2) | (3) | (4) | (5) | (6) |
| Log of Bilateral Trade | $\log(X_{ij})$ | $\log(X_{ij})$ | $\log(X_{ij})$ | $\log(X_{ij})$ | $\log(X_{ij})$ | $X_{ij} > 0$ |
| Log of Working Ratio of Exporter | – | 7.11** | 7.16** | 7.50** | 2.81** | 5.61** |
| | | (98.27) | (86.50) | (22.03) | (10.85) | (.000) |
| Log of Working Ratio of Importer | – | 5.88** | 5.92** | 2.50** | 1.88** | 5.81** |
| | | (94.03) | (81.46) | (4.09) | (8.31) | (.000) |
| Log of Distance | -1.01*** | -0.97** | -1.02** | -0.93** | -1.47** | -0.64** |
| | (-123.27) | (-133.26) | (-131.90) | (-13.09) | (-186.27) | (.000) |
| Log of Wages of Exporter | 0.45** | 0.33** | 0.36** | 0.27** | 0.15** | 0.32** |
| | (163.81) | (113.43) | (104.68) | (24.40) | (24.30) | (.000) |
| Log of Wages of Importer | 0.39** | 0.30** | 0.32** | 0.11** | 0.16** | 0.39** |
| | (136.47) | (105.78) | (96.05) | (7.01) | (26.56) | (.000) |
| Log of Population of Exporter | 1.04** | 0.98** | 1.00** | 1.04** | 0.28** | 0.84** |
| | (261.53) | (253.29) | (235.71) | (70.06) | (3.61) | (.000) |
| Log of Population of Importer | 0.90** | 0.87** | 0.88** | 0.30 | 0.62** | 0.88** |
| | -220.72 | (220.32) | (205.54) | (1.48) | (9.55) | (.000) |
| Log of CPI of Exporter | – | – | 0.11** | -0.10** | 0.01 | -0.20** |
| | | | (19.99) | (-7.00) | (1.34) | (.000) |
| Log of CPI of Importer | – | – | 0.08** | -0.03** | -0.03** | -0.10** |
| | | | (13.82) | (-2.23) | (-4.81) | (.000) |
| Number of observations | 130,359 | 130,359 | 107,346 | 107,346 | 107,346 | 107,346 |
| Contry-pair-specific Fixed Effects | No | No | No | Yes | No | No |
| Year-specific Fixed Effects | No | No | No | Yes | Yes | Yes |
| Time-varying Country Fixed Effects | No | No | No | No | Yes | No |
| (Pseudo) R-squared | 0.45 | 0.52 | 0.53 | 0.39 | 0.73 | .82 |

Notes: Numbers in parenthesis except the last column are t-values whereas number in parenthesis in the last column are p-value. *(**) indicates significance at 1 (5) percent level.

Table 3: Industry-Level Estimations

| Method | OLS | FE | | PPML |
|---|---|---|---|---|
| Regressand: | (1) | (2) | (3) | (4) |
| Log of Bilateral Trade | $\log(X_{ijk})$ | $\log(X_{ijk})$ | $\log(X_{ijk})$ | $X_{ijk} > 0$ |
| Log of Working Ratio of Exporter | 5.27** | 4.11** | .99** | 4.35** |
| | (86.93) | (12.35) | (4.82) | (.000) |
| Log of Working Ratio of Importer | 5.14** | 2.55** | 3.19** | 3.20** |
| | (104.9) | (4.74) | (17.87) | (.000) |
| Log of Distance | -0.80** | -0.87** | -1.06** | -0.89** |
| | (-152.1) | (-15.65) | (-167.1) | (.000) |
| Log of Wages of Exporter | 0.21** | 0.20** | .01** | 0.41** |
| | (85.10) | (27.16) | (2.88) | (.000) |
| Log of Wages of Importer | 0.16** | 0.07** | .03** | 0.51** |
| | (70.09) | (4.55) | (6.41) | (.000) |
| Log of Population of Exporter | 0.68** | 0.73** | 1.39** | 0.87** |
| | (213.9) | (61.11) | (22.59) | (.000) |
| Log of Population of Importer | 0.61** | -0.17 | .90** | 0.93** |
| | (199.1) | (-1.21) | (17.91) | (.000) |
| Log of CPI of Exporter | -0.07** | -0.06** | -.15** | -0.07** |
| | (-19.0) | (-5.34) | (-31.01) | (.000) |
| Log of CPI of Importer | -0.12** | -0.03** | -.20** | -0.02** |
| | (-31.18) | (-2.30) | (-39.36) | (.000) |
| Number of observations | 493,921 | 493,921 | 493,921 | 493,921 |
| Contry-pair-specific Fixed Effects | No | Yes | No | No |
| Industry-specific Fixed Effects | No | Yes | Yes | Yes |
| Year-specific Fixed Effects | No | Yes | Yes | Yes |
| Time-varying Country Fixed Effects | No | No | Yes | No |
| (Pseudo) R-squared | 0.23 | .38 | .29 | .89 |

Notes: Numbers in parenthesis except the last column are t-values whereas number in parenthesis in the last column are p-value. *(**) indicates significance at 1 (5) percent level.

Table 4: Additional Estimates: Alternative Measures of Wages (1983-2003)

| Method | OLS | FE | | PPML |
|---|---|---|---|---|
| Regressand: | (1) | (2) | (3) | (4) |
| Log of Bilateral Trade | $\log(X_{ij})$ | $\log(X_{ij})$ | $\log(X_{ij})$ | $X_{ij} > 0$ |
| Log of Working Ratio of Exporter | 7.29** | 6.19** | 4.70** | 15.71** |
| | (16.79) | (3.56) | (2.51) | (.000) |
| Log of Working Ratio of Importer | 5.09** | 3.21** | 6.18** | 14.78** |
| | (14.42) | (.73) | (3.81) | (.000) |
| Log of Distance | -0.81** | -.93** | -1.16** | -1.08** |
| | (-27.89) | (-3.91) | (-39.17) | (.000) |
| Log of Wages of Exporter | 0.28** | .54** | .43** | 0.32** |
| | (10.15) | (5.01) | (3.87) | (.000) |
| Log of Wages of Importer | 0.29** | .35** | -.01 | 0.24** |
| | (11.85) | (2.25) | (-.07) | (.000) |
| Log of Population of Exporter | 0.44** | .53** | -1.87** | 0.63** |
| | (24.98) | (7.32) | (-3.53) | (.000) |
| Log of Population of Importer | 0.46** | 1.46 | 2.56** | 0.56** |
| | (29.40) | (1.38) | (5.02) | (.000) |
| Log of CPI of Exporter | -0.07* | -.18** | -.06** | 0.30** |
| | (-3.28) | (-3.13) | (-1.73) | (.000) |
| Log of CPI of Importer | 0.00 | .16** | .07** | 0.26** |
| | (.05) | (2.80) | (2.10) | (.000) |
| Number of observations | 6,500 | 6,500 | 6,500 | 6,500 |
| Contry-pair-specific Fixed Effects | No | Yes | No | No |
| Year-specific Fixed Effects | No | Yes | Yes | Yes |
| Time-varying Country Fixed Effects | No | No | Yes | Yes |
| (Pseudo) R-squared | .32 | .31 | .57 | .62 |

Notes: numbers in parenthesis in first three columns are t-values whereas numbers in the last column are p-value. *(**) indicates significance at 1 (5) percent level.

Table 5: IV Estimations, using Country-level Life Expectancy as IV

| Regressand: | IV | IV | IV+FE | IV+MR |
|---|---|---|---|---|
| Log of Bilateral Trade: $\log(X_{ij})$ | (1) | (2) | (3) | (4) |
| Log of Working Ratio of Exporter | 14.32** | 12.74** | 17.68** | 20.29** |
| | (225.73) | (122.56) | (94.09) | (4.39) |
| Log of Working Ratio of Importer | 13.05** | 10.48** | 1.55 | 7.81* |
| | (208.94) | (103.74) | (0.64) | (1.87) |
| Log of Distance | | -0.97** | -1.04** | -1.47** |
| | | (-111.52) | (-64.35) | (-184.92) |
| Log of Wages of Exporter | | 0.29** | 0.23** | 0.08** |
| | | (74.90) | (66.37) | (9.70) |
| Log of Wages of Importer | | 0.27** | 0.10** | 0.09** |
| | | (71.57) | (13.97) | (11.24) |
| Log of Population of Exporter | | 0.97** | 1.04** | -2.09** |
| | | (200.78) | (211.89) | (-4.99) |
| Log of Population of Importer | | 0.87** | 0.49** | -0.74** |
| | | (185.01) | (2.62) | (-2.07) |
| Log of CPI of Exporter | | 0.20** | -0.07** | 0.04** |
| | | (32.92) | (-12.57) | (5.83) |
| Log of CPI of Importer | | 0.15** | -0.03** | -0.01 |
| | | (24.51) | (-4.27) | (-1.01) |
| Kleibergen-Paap rk LM $\chi^2$ statistic | 198,476 | 57,787 | – | 158.9 |
| Kleibergen-Paap rk Wald F statistic | 254,091 | 65,893 | – | 79.36 |
| Number of observations | 325,668 | 102,904 | 102,904 | 102,904 |
| Contry-pair-specific Fixed Effects | No | No | Yes | Yes |
| Year-specific Fixed Effects | No | Yes | Yes | Yes |
| Time-varying Country Fixed Effects | No | No | No | Yes |
| R-squared | 0.19 | 0.48 | .41 | 0.72 |
| First-Stage Estimates | | | | |
| Life Expectancy of Exporter | .007** | .008** | .006** | .001** |
| | (725) | (383) | (211) | (35.32) |
| | [.000] | [.000] | [.000] | [.000] |
| Life Expectancy of Importer | .007** | .008** | .002** | .002** |
| | (718) | (386) | (33.84) | (37.03) |
| | [.000] | [.000] | [.000] | [.000] |

Notes: numbers in parenthesis are t-values whereas numbers in brackets in the first-stage estimates indicates Prob.>F-statistic. *(**) indicates significance at 1 (5) percent level.

Table 6: Fixed-Effects Estimations by Origin and Destination

| Regressand: Log of Bilateral Trade $\log(X_{ij})$ | Exports from DCs to DCs (1) | Exports from DCs to LDCs (2) | Exports from LDCs to DCs (3) | Exports from LDCs to LDCs (4) |
|---|---|---|---|---|
| Log of Working Ratio of Exporter | 1.37 | -1.98** | 8.50** | 7.70** |
| | (1.47) | (-2.70) | (18.87) | (14.10) |
| Log of Working Ratio of Importer | 5.97** | 1.49** | 4.00* | -0.20 |
| | (5.19) | (2.07) | (1.72) | (-0.20) |
| Log of Distance | -1.22** | -0.83** | 0.20 | -1.35** |
| | (-9.49) | (-6.46) | (-1.47) | (-13.04) |
| Log of Wages of Exporter | 0.12** | 0.23** | 0.23** | 0.25** |
| | (4.45) | (13.94) | (11.91) | (13.94) |
| Log of Wages of Importer | 0.10** | 0.14** | 0.10** | 0.10*** |
| | (2.87) | (6.67) | (2.42) | (3.73) |
| Log of Population of Exporter | 0.80** | 1.09** | 1.02** | 0.98** |
| | (22.13) | (47.84) | (40.83) | (33.92) |
| Log of Population of Importer | 0.68** | -0.67** | 0.78 | -0.53 |
| | (2.02) | (-2.20) | (1.03) | (-1.33) |
| Log of CPI of Exporter | -0.38** | -0.40** | -0.09** | -0.04** |
| | (-11.05) | (-16.90) | (-3.58) | (-1.97) |
| Log of CPI of Importer | -0.04* | -0.09** | -0.01 | -0.01 |
| | (-1.80) | (-6.25) | (-0.14) | (-0.43) |
| Number of observations | 12,150 | 30,474 | 29,467 | 35,255 |
| Contry-pair-specific Fixed Effects | No | Yes | No | No |
| Year-specific Fixed Effects | No | Yes | Yes | Yes |
| R-squared | 0.72 | 0.52 | 0.35 | 0.31 |

Notes: numbers in parenthesis are t-values. *(**) indicates significance at 1 (5) percent level.

Table 7: Decadal Fixed-Effects Estimates for Multilateral Resistance

| Regressand: Log of Bilateral Trade | OLS $\log(X_{ijk})$ | FE $\log(X_{ijk})$ | FE+IV $\log(X_{ijk})$ | PPML $X_{ijk} > 0$ |
|---|---|---|---|---|
| *Period 1970-1979* | | | | |
| Log of Working Ratio of Exporter | 10.97** | 7.31** | 29.50** | 4.50** |
| | (43.22) | (10.12) | (20.63) | (.000) |
| Log of Working Ratio of Importer | 10.30** | -2.60 | -3.42 | 7.41** |
| | (42.66) | (-1.31) | (-0.10) | (.000) |
| # of Obs. | 9,101 | 9,101 | 7,805 | 9,101 |
| *Period 1980-1989* | | | | |
| Log of Working Ratio of Exporter | 9.77** | 7.26** | 21.70** | 5.41** |
| | (64.03) | (15.92) | (42.50) | (.000) |
| Log of Working Ratio of Importer | 9.33** | 4.72** | -4.54 | 6.56** |
| | (69.87) | (2.85) | (-1.22) | (.000) |
| # of Obs. | 24,044 | 24,044 | 21,301 | 24,044 |
| *Period 1990-1999* | | | | |
| Log of Working Ratio of Exporter | 7.17** | 6.18** | 14.14** | 6.27** |
| | (57.19) | (13.57) | (53.36) | (.000) |
| Log of Working Ratio of Importer | 7.02** | 3.81** | 11.83 | 5.90** |
| | (63.68) | (3.78) | (0.48) | (.000) |
| # of Obs. | 37,060 | 37,060 | 36,876 | 37,060 |
| *Period 2000-2006* | | | | |
| Log of Working Ratio of Exporter | 9.68** | 9.68** | 17.38** | 5.39** |
| | (65.29) | (22.81) | (61.50) | (.000) |
| Log of Working Ratio of Importer | 6.87** | 5.24** | 39.01** | 5.73** |
| | (49.77) | (4.05) | (3.37) | (.000) |
| # of Obs. | 37,141 | 37,141 | 36,922 | 37,141 |
| Industry-specific Fixed Effects | No | Yes | Yes | Yes |
| Year-specific Fixed Effects | No | Yes | Yes | Yes |
| Time-varying Country Fixed Effects | No | No | Yes | Yes |

Notes: Numbers in parenthesis except the last column are t-values whereas number in parenthesis in the last column are p-value. *(**) indicates significance at 1 (5) percent level.

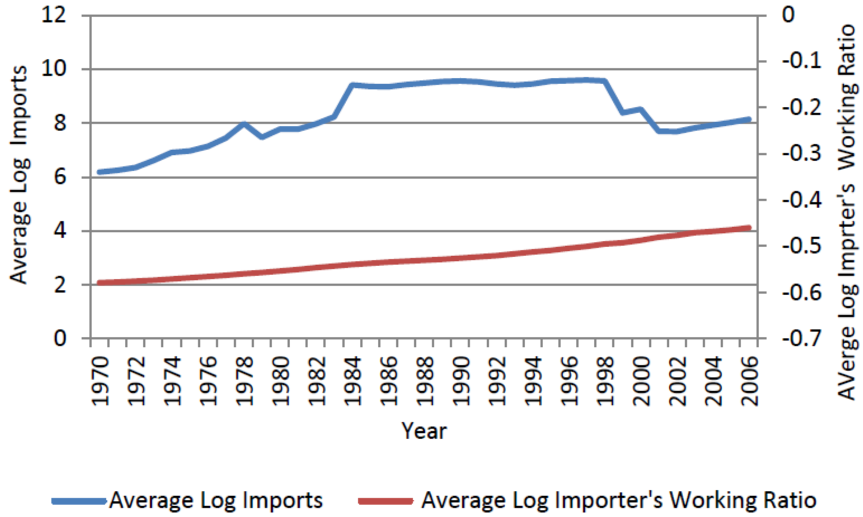



Figure 1: Bilateral Trade Flow and Importer's Working Ratio (1970-2006)

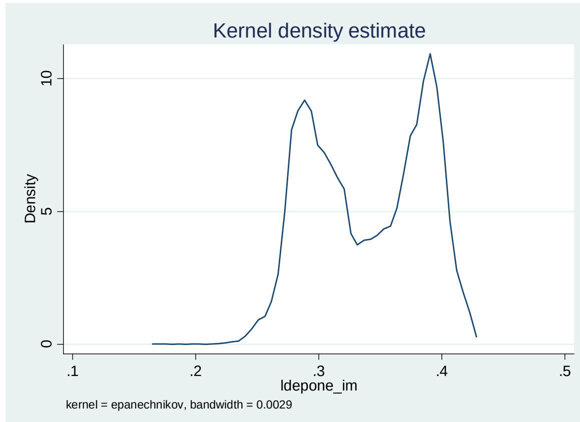



Figure 2A Density Distribution of Log of Dependency Ratio for All Countries

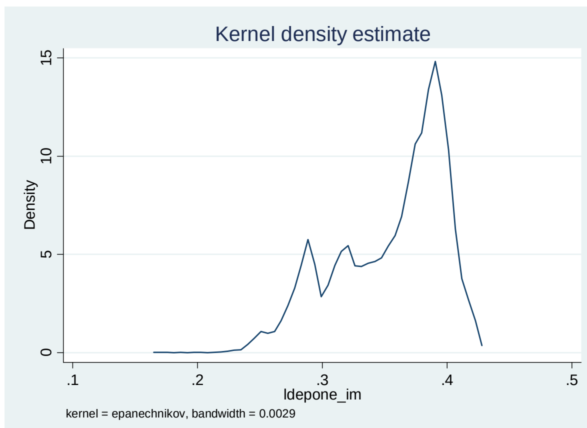



Figure 2B Density Distribution of Log of Dependency Ratio for Non-OECD Countries

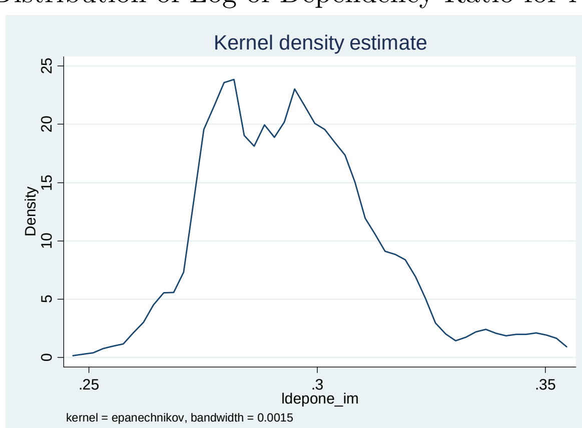
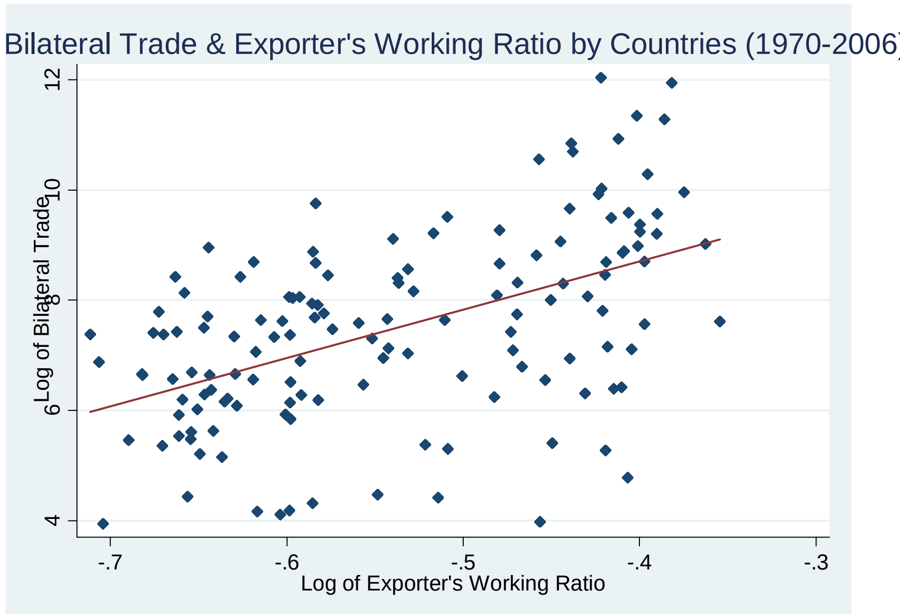
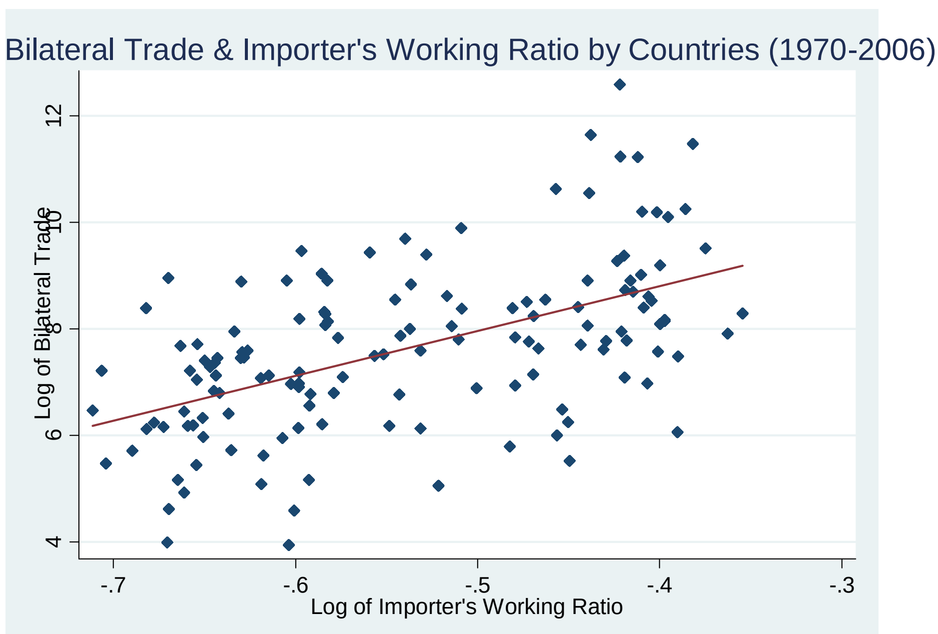



Figure 2C: Density of Log of Dependency Ratio for OECD Countries

Figure 2: Distributions of Dependency Ratio (1970-2006)




A. Log of Bilateral Trade against Log of Exporter's Working Ratio




B. A. Log of Bilateral Trade against Log of Importer's Working Ratio

Figure 3: Working Ratio and Bilateral Trade