The Impacts of Globalization on Wage Inequality in Taiwan Manufacturing: Evidence from Quantile Regression Analyses

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This paper is prepared for the 2006 International Symposium on Contemporary Labor Economics, December 16-18, 2006, the Wang Yanan Institute for Studies in Economics, Xiamen University, China. This paper is a sub-project of the main research project “Advancement of Research on Econometrics Methods and Applications (AREMA)”.

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Abstract

In contrast with the conventional macro analysis, this study uses micro data to examine the impacts of globalization on the wage inequality in Taiwan’s manufacturing industry, with a focus on various marginal effects derived from import, export and outward investment with respect to trade partners of different levels of development. The empirical results based on the estimation of quantile regressions show that the effects of globalization indeed vary in accordance with types of trade partners and are heterogeneous across the conditional distribution of wage. It is suggested that “wage ratio” equation based on macro data cannot fully reveal the effects of internationalization on wage inequality. Moreover, neglect of outward investment in the analysis of wage structure under globalization may result in omitted variable problem.

Keywords: globalization, quantile regression, wage inequality, outward investment

JEL classification: C20, F00, J31
1. Introduction

The increase of Taiwan’s globalization over the past 3 decades is one of the reason to keep the vitality of the economy. The economic openness in recent years, however, has accompanied the worsening of wage inequality. As denoted by the annual report of the Survey of Family Income and Expenditure (SFIE), 2001 was the year with the worst income distribution as well as the largest deterioration of income inequality over the past half century. Gini coefficient reached 0.35 record high in year 2001, and the ratio of top to bottom quintiles expanded sharply from 3.49 in year 2000 to 6.39 in year 2001, and male wage quintile ratio rose from 4.10 to 4.37 (Chen and Chen, 2002) during the same time. All these inequality measures reached record high and unprecedented severity.

From the aspect of Taiwan’s openness, total volume of imports and exports in year 2000 was 14.8 billion and 14 billion US dollars, with annual growth rate of 17% and 22%, respectively. Growth of trade and foreign direct investment (FDI) across the Taiwan strait were even faster over the same period. Trade volume between Taiwan and China exceeded 11.5 billion with 18% annual growth rate. Approved outward investment to China increased very fast as it was doubled in 2000 than in 1999, reached 2.6 billion, then further increased to 2.8 billion in 2001. It is evident that the income distribution and wage differentials are highly correlated with globalization and the relationship between openness and income differentials has long been a essential issue of international economics in both theoretical and empirical aspects. Subject to data availability, most of the empirical studies focus on the analyses of macro data, existing literature that exerting micro data to discuss the linkage between wage inequality and international trade is indeed rare.

The purpose of this study is to investigate the cause of wage changes across the overall distribution in accordance with the expansion of import, export and outward investment. By combing micro data with industrial level openness index, the cross-sectional time series data source enable us to examine the impact of globalization on the change of wage level at
individual level. Meanwhile, this study employs the newly developed quantile regression technique to observe the separate impacts of openness on workers of different skills across the wage distribution. It is expected to derive new evidence from the pioneered data arrangement and econometric technique of this study.

There are abundant studies focusing on the change of wage differential along the process of globalization. Theoretical models have been well developed since Jones (1956) and Mundell (1957). Although the predicted direction of changing wage differential in response to the expansion of trade and outward investment are explicit, there is little consensus in empirical literature. In terms of aggregate aspect studies, Murphy and Welch (1991), Leamer (1992), Borjas and Ramey (1994), Wood (1995), among others, all conclude that openness (including trade, FDI and outsourcing) play significant roles in explaining the dispersion of wage structure. In contrast, Katz and Murphy (1992), Bound and Johnson (1992), Krugman and Lawrence (1993), Lawrence and Slaughter (1993) and Sachs and Shatz (1996) all agree that trade has limited ability to explain the variation of wage differentials.

In addition to the studies of single country aggregate data on wage differentials, Bourguignon and Morrison (1990), Edward (1997) and Mahler et al. (1999) examine the interaction between income distribution and openness under cross-country framework. Within them, Mahler et al. (1999) use Luxemburg Income Study (LIS) micro data archive to investigate the effects of two major components of globalization – net trade and FDI – on income differential, and their findings suggest that a country’s openness plays no role in the determination of income distribution.

There are many representative domestic studies focusing on the related issues, Lin (1998), Chan et al. (1999), Chen and Hsu (2001), Chang (2002), Lin and Chu (2002) and Chen and Tsaur (2006), among others, are some representatives who analyze the influence of international trade on skilled and unskilled wage inequality. Lin (1998) uses industrial Census data to identify the facts that wage inequality is positively correlated with the expansion of
export and outward investment. Chan et al. (1999) focus on the influences of technological and educational improvements on wage inequality, and find that structure change of trade and technology advancement evidently reduced wage discrepancies that is consistent with the conclusion of Lin and Chu (2002). Chen and Hsu (2001) extend the traditional two trade partners (high- and low-developed countries) framework to three layers of trading countries (developed, semi-developed, and developing) in the analysis of the effect of trade on wage inequality. According to their extended model, it is suggested that Taiwan, a semi-developed country, exports to higher developed countries, e.g., OECD, will enlarge the wage gap while the reverse is true when Taiwan exports to relatively lower developed ones. Their findings, however, contradict with the predictions of traditional model.

Different from the studies using aggregate data, Tsou (2002) is the first one implement a two stage analyses with the first state using micro data to estimate industrial specific wage to merge with indusial level trade measurements, and the second stage is to estimate an industrial level wage function which accounts for the effects of globalization. With more precise estimates of wage ratio from micro data, findings of Tsou (2002) are basically consistent with that of Chan et al. (1999) and Lin and Chu (2002). Furthermore, Chang (2002) attempts to explain wage differentials in Taiwan by using Dynamic Intertemporal General Equilibrium model to perform statistical simulation with distinction of short- and long-run effects in empirical estimates. It is concluded that education, international (net) trade as well as productivity growth are relevant to explain Taiwan’s wage differentials. Although all these studies using domestic data source reach a consensus that there is evident correlation between trade and wage inequality, no study sheds light on the possible short-term phenomenon of globalization on wage inequality.

Since the late 90’s, the rapid expanding China economic induces more trades with and FDI from Taiwan and results in worsening wage distribution and increasing unemployment, unskilled labor in particular (Lin and Huang, 2005). It is suggested that the China economy
booming since late 90’s may cause different impacts on Taiwan than that of before. Nevertheless, the traditional aggregate data study is not able to deal with the short term micro aspect analyses that focus on the recent years. Besides, since the data of FDI from Taiwan to China is not available prior to early 90’s, few studies take the potential impact of FDI on wage inequality because it is not easy to take short period FDI measure into a time series analysis.

There is a series data limitation that hinders the use of micro data from the discussion of trade on wage. According to the documentation of trade, import and export volumes and values are recorded by CCC codes or SITC codes (Directorate General of Customs, 2004) that cannot directly link to the categorization of manufacture industries of wage survey. The inconsistency of categorization grouping between trade and wage data further prevent the use of micro data in the analysis of globalization.

In order to provide new evidences on the effects of internalization on wage differential over a relatively short period of time, this study uses combined individual and industrial level data to address the issue of wage changes with respect to opening trade and accelerating outward investment. Focus of this study is to analyze the changing wage structure when Taiwan faces the drastic change of both international trade and industry outward migration since the late 90’s. It is worth to note that traditional macro studies estimate the change of high and low skilled workers’ wage ratio with respects to openness and macroeconomic performance. The “wage ratio” equation can only infer the divergence or convergence between high and low skilled wages, the increase or decrease of individual skilled level wage under the impact of internationalization is actually ambiguous. By applying quantile regression technique on micro data, this study is able to identify the marginal effects of openness on wages across the whole distribution to observe the changes of wages of different skills by construction without artificially design high-low skilled workers.

Additionally, trade between countries of various stages of development might result in
different effects on wage of various skill levels, same as FDI to different types of countries. Chen and Hsu (2001) define Taiwan as a semi-developed country, and they find that trading with developed and low-developed countries may cause different effects on wage differential. This study follows the same types of categorization of Chen and Hsu (2001) to stratify Taiwan’s trade partners and FDI destination countries to different groups according to development stages. As mentioned above, data arrangements and model specifications of this study are of new trials in the literature. Findings of this study is hope to add complementary evidences to the traditional macro aspect analyses.

Main findings of this study are as follows. First, the effect of net trade on wage can’t be misleading since import and export result in various effects on various skilled wages. It is suggested that macro aspect “wage ratio” equation can’t exactly reveal the effects of internationalization on wage inequality due to the fact that responses of wages to openness are not homogenous across the distribution. Furthermore, the ignorance of FDI on wage equation is possible to subject to missing variable problem. Second, imports from China benefited median and higher skilled wages for year 1999-2001, the higher wage the larger benefit is; the reserve is true for the median and lower skilled wages for year 2002-2004. It is suggested that the economic status between the Straits has been changing from complement to competitive. Export to China has no effect in 1999-2001 and it seems to favor Taiwan’s wage during 2002-2004 with larger benefit for higher skilled workers. As Taiwan is more developed than China, the result is consistent with the prediction of traditional international economics model. Third, FDI to China shows various effects across wage distribution and time span. During 1999-2001, given fixed R&D, FDI to China per se disadvantages low skilled wages but advantages high skilled wages that reflects the comparative advantages between the two economies. Nevertheless, this pattern changes in 2002-2004 that FDI to China itself lowered most worker’s wage except the very low skilled. With the consideration of R&D, FDI to China on wage will induce further effects and the total effects of FDI to China depend on FDI
and R&D accordingly. In 1999-2001, FDI to China benefited low skilled wage as long as there was enough R&D. Given fixed FDI to China, higher R&D resulted in lower wages of high skilled. In 2002-2004, R&D plays no role in the determination of wages and FDI to China is disadvantageous to most skilled wages except the very low skilled ones. It implies that industries with higher R&D will depress domestic wages if they have FDI to China at the same time. It is suggested that high technology industries have to be cautious in making their worldwide investment strategies.

There are five sections of this paper. After the introduction, section II illustrates the related theories and set out the empirical models for estimates. Section III describes the data sources and presents general statistics of the variables in the model. Sections IV shows the results of empirical estimates with different types of model specifications to demonstrates the marginal effects of imports, exports, outward investment and lagged outward investment on skilled and unskilled labor with respect to countries of different levels of development. Section V are the concluding remarks and the limitation of this study.

2. Theoretical Background and Empirical Models

Wage differential caused by internationalization can be induced by two major channels: international trade and FDI. Heckscher-Ohlin-Samuelson (HOS) model is the dominant theory in international economics explaining the association of wage differential and international trade. HOS theory explicitly predicts a one to one relationship between trade directions and factor price (wage). Since international trade changes the demand and supply of outputs so as the relative prices, changing output prices affect the relative price of inputs. HOS model predicts that within two trade partners, higher developed country will export skilled products and import unskilled ones, the reverse is true for lower developed counterpart.

Consequently, increasing trade will increase skilled wage while decrease unskilled wage
in the higher developed countries and therefore wage differential disperse. Lower developed countries’ wage differential reduces because increasing trade decreases skilled wage and increases unskilled wage. Theoretical prediction of the changing direction of wage differential is decisive while empirical evidences are not conclusive. Sachs and Shatz (1996) suggest that outward investment, monopoly behavior and skill-biased technology improvement may cause the discrepancies between theoretical predictions and empirical findings.

On the other hand, Mundell (1957) is the fundamental study providing the essential theoretical explanation for the causation of outward investment on wage differentials. Mundell (1957) concludes that factor migration and commodity trade substitute for each other. Under the theories of factor and commodity prices equalization, the welfare effect of outward investment on labor is identical to that of international trade under H-O-S model. Similarly, from the view point of multi-national industry, outward investment is the movement of capital from host country to guest country to take the advantage of cheaper labor and raw materials in production, and then sells back to host country or the third countries (Hymer, 1960; Kojima, 1973; Dunning, 1981). Out-sourcing production mode enforced by FDI decreases the demand of unskilled workers at both trade and non-trade sectors and consequently harms unskilled wages. Lowering transaction costs (including communication, coordination and transportation) between the host and guest countries induced by the increase of outward investment will enlarge the effect on wages. Nevertheless, there is no consensus on the relationship between outward investment and international trade. Glejser (1976), Lipsey and Weiss (1981) and Blomstrom (1988) conclude that outward investment plays similar role as trade in affecting wage differentials. On the contrary, findings of Stobaugh (1976), Bergsten et al. (1978), Orr (1991), Kravis and Lipsey (1992) and Cave (1996) stress that outward investment is complimentary to trade.

Due to the fact that the relationship between outward investment and international trade
are inclusive with their effects on wage differential are seldom discussed simultaneously in empirical estimates, this study attempt to reconcile the inconclusiveness between theoretical model and empirical results by controlling trade and outward investment at a time with detailed stratification of trade partners. By combing micro data with industrial level indexes, this study employ standard Mincerian human capital model (Mincer, 1974) within the structure of quantile regression to discuss the change of wages of various skill, i.e., wage across the distribution, with respect to the level of internationalization across industries. The human capital model augmented with openness indicators within least square regression can be expressed as:

\[
\ln(W_i) = X_i^1 \beta_1 + X_i^2 \beta_2 + \epsilon_i, \quad i = 1 \ldots n. \quad (1)
\]

where \(W_i\) is wage of individual \(i\), \(X_i^1\) is the vector of human capital characteristics of the \(i^{th}\) individual and \(X_i^2\) industrial characteristics of the \(i^{th}\) individual’s industry. \(\epsilon_i\) is error term. \(\beta_1\) and \(\beta_2\) are estimated coefficients corresponding to \(X_i^1\) and \(X_i^2\). Covariates of human capital include schooling year, linear and quadratic terms of experience.\(^1\) In terms of industrial characteristics, we incorporate the ratios of import, export, FDI and R&D times FDI over GDP of each industry to control the effects of internationalization and technology advancement on the variation of wages.

Other than the least square regression, Equation (1) can be estimated by the method of quantile regression proposed by Koenker and Bassett (1978). Let \(\theta\) be a real number in \((0, 1)\). In accordance with Equation (1), the regression specification of the \(\theta^{th}\) conditional quantile can be expressed as

\[
\theta \ln(W_i) = X_i^1 \beta_{1\theta} + X_i^2 \beta_{2\theta} + \epsilon_{i\theta}, \quad i = 1, 2, \ldots, n, \quad (2)
\]

where \(\beta_{1\theta}\) and \(\beta_{2\theta}\) is the vector of parameters that depend on \(\theta\), and \(\epsilon_{i\theta}\) is the corresponding error. The quantile regression estimate \(\hat{\beta}_{1\theta}\) and \(\hat{\beta}_{2\theta}\) is obtained by minimizing the asymmetric weighted sum of absolute deviation:

\(^1\) Experience here is standard potential experience defined by Mincer (1974) as age – schooling – 6.
\[
\min_{\beta \in \mathbb{R}^k} \left[ \sum_{i=1}^{n} \left( \theta \ln W_i - X_i' \beta_1 - X_i' \beta_2 \right) + \sum_{i=1}^{n} \left( 1 - \theta \right) \ln W_i - X_i' \beta_1 - X_i' \beta_2 \right], \tag{3}
\]

and \( X_1' \beta_{1\theta} + X_2' \beta_{2\theta} \) is an approximation to the \( \theta \)th conditional quantile of \( \ln W \). When \( \theta \) is close to zero (one), \( X_1' \beta_{1\theta} + X_2' \beta_{2\theta} \) characterizes the behavior of \( \ln W \) at the left (right) tail of the conditional distribution. When \( \theta = 1/2 \), Equation (3) is equivalent to the objective function of LAD estimation, so that \( X_1' \beta_{1\theta} + X_2' \beta_{2\theta} \) describes a “center” (the median) behavior of \( \ln W \).

The first order condition of (3) is

\[
\sum_{i=1}^{n} \left[ \theta - \frac{1}{2} \right] \left[ \frac{1}{2} \right] \text{sign} \left( \ln W_i - X_i' \beta_1 - X_i' \beta_2 \right) X_i = 0, \tag{4}
\]

where \( \text{sign} \left( \lambda \right) = I \left( \lambda \geq 0 \right) - I \left( \lambda \leq 0 \right) \) with \( I \left( A \right) \) the indicator function of the event \( A \). Clearly, Equation (4) is not differentiable at the optimum. Thus, standard numerical optimization algorithms do not work. Koenker and Bassett (1978) and Koenker and D’Orey (1987) propose the use of linear programming to estimate \( \beta_\theta \) in Equation (4). Under some regularity conditions, the asymptotic distribution of \( \hat{\beta}_\theta \) is

\[
\sqrt{n} \left( \hat{\beta}_\theta - \beta_\theta \right) \xrightarrow{d} \mathcal{N}(0, \Lambda),
\]

where \( \Lambda \) is the asymptotic covariance matrix:

\[
\Lambda = \theta(1-\theta) \left( E[f_{e|X,\theta}(0 \mid X_i)X_iX_i'] \right)^{-1} E[X_iX_i'] \left( E[f_{e|X,\theta}(0 \mid X_i)X_iX_i'] \right)^{-1},
\]

and \( f_{e|X,\theta} \) is the conditional probability density of the error term; see Koenker (2005) for a comprehensive treatment of quantile regression. A convenient way to estimate \( \Lambda \) is the bootstrap method (Efron, 1982). Specifically, \( m \) observations are drawn (with replacement) from the total sample of \( X \) and \( S \) to constitute a sub-sample of \( X^* \) and \( S^* \), and a bootstrap estimate \( \hat{\beta}_{\theta} \) is computed from the sub-sample. This procedure is then repeated \( B \) times to yield a collection of bootstrap estimates \( \hat{\beta}_{\theta j} \), \( j = 1 \ldots B \). The estimator of the asymptotic
covariance matrix $\Lambda$ is then computed as

$$\hat{\Lambda} = m \left( \frac{1}{B} \sum_{j=1}^{B} (\hat{\beta}_{\theta_j} - \beta_{\theta}) (\hat{\beta}_{\theta_j} - \beta_{\theta})' \right).$$  \hspace{1cm} (5)$$

The bootstrap estimate of the asymptotic covariance matrix is proved to be fairly robust (Buchinsky, 1992). This study uses STATA 8.0 which adopts the algorithm of Armstrong et al. (1979) to compute $\hat{\beta}_{\theta}$ and the bootstrap method for computing $\Lambda$. In our estimation, $m$ in equation (5) is set to $n$ and $B$ (the number of bootstrap repetition) is set to 1,000.

The quantile regression estimate $\hat{\beta}_{\theta}$, represents the marginal effects of covariates upon log wage, depending on the location of the conditional distribution of wage. Such effect may vary across the distribution. If the conditional distribution of wage is not homogenous, the estimated slope coefficients of quantile regression are expected to deviate from that of OLS and LAD (Koenker, 2005). Also, the discrepancies of the marginal effects between tail quantiles characterize the heterogeneity of different groups of workers. Thus, the economic implications and policy suggestions derived from quantile regressions would be more enriched than that from traditional OLS and LAD regressions.

Following the trade partner stratification of Chen and Hsu (2001), we defined Taiwan as a semi-developed country and divided trade areas and outward investment guest countries into three groups: firstly, countries with higher than or equal to Taiwan’s development stage, such as Japan, Korea and OECDs (coded as ASOE); secondly, countries with lower to Taiwan’s development stage (coded as ASNO), such as India, Vietnam and the non-OECD countries; finally, China as one of its kind. Since 1987 Taiwan government officially permitted outward investment to China, and China soon became Taiwan’s major trade partner as well as the majority of FDI destination. We therefore separate China out of other trade partners.

In equation (1) and (2), indicators of internationalization includes the ratio of import,
export and outward investment over industrial specific GDP. Other than that, R&D is supposed to be significantly affects wage. Due to the high correlation between R&D and FDI, the model controls R&D times FDI in stead of R&D itself. The estimated coefficient at low conditional quantile represents the marginal effect of openness on low-skill wage. Correspondingly, the marginal effect of internationalization on high-skill wage is estimated by high conditional quantile. A significant and positive coefficient of the R&D and FDI interaction term implies the effects of R&D depends on the level of FDI. As an example, if there is no R&D of some industry, the effects of FDI will be lack of the interaction term.

According to the traditional H-O-S model, if Taiwan trades with OECD or higher developed countries, low-skilled labor is benefited and high-skilled one is hurt and consequently results in decreasing wage differential. If Taiwan trades with Asian lower developed countries (including China), Taiwan will import low-skilled products from and export high-skilled products to these partners, resulting in decreasing low-skill wage but increasing high-skilled wage with the expansion of wage differential. Findings of Chen and Hsu (2001), however, contradicts the prediction of H-O-S model. It is documented that wage differential is negatively associated with Taiwan’s net trade to non-OECD and China while net trade with OECD countries is positively associated with wage differential due to technology learning process that benefits high-skill worker.

It is worth to note that these results are derived from the effect of net trade on high- and low-skilled wage ratio. Within the structure of “wage ratio” equation, the individual effects of import and export respectively of different area on high- and low-skilled wage are actually ambiguous since changes of the ratio reveals little information of the rise or fall of high- and low-skilled wages separately. Besides, the effect of trade (including import and export) on wages can’t directly infer to the effect of net exports alone unless the marginal effects of import and export are of equal magnitudes but opposite signs. With these constraints, the aggregate data analysis seems not be able to provide complete pictures of the interaction
between trade and wage differential.

According to the theory of Mundell (1957), outward investment and commodity trade are perfect substitutes. Therefore, Taiwan’s FDI to China and lower developed countries will hurt low-skill wage and expand wage differential because low-skill workers were replaced by cheaper ones in guest countries. Taiwan’s outward investments to higher developed countries will benefit low-skill worker and wage differential shrinks. From the aspect of multi-national enterprises, however, outward investment reflects not only the consideration of comparative advantage but also new technology learning (Wood, 1995). In the former case outward investment and trade are substitute while the latter, complement. The total effects of outward investment on high- and low-skill wage is an empirical question and that is determined by the dominant effect between comparative advantage and market integration (technology advancement).

3. Data and Descriptive Statistics

Data used for empirical estimates in this study are of various sources. Focusing on the phenomenon of changing wage differential in recent year between 1999 and 2004, the data of wage and labor’s characteristics are from Manpower Utilization Survey (MUS) which is conducted by Directorate-General of Budget, Accounting and Statistics (DGBAS), Executive Yuan of Taiwan government. MUS is one of the two large scale household surveys in Taiwan which started collecting since 1978. Sample households of MUS are around 20,000 each year with about 70,000 civilians. Manufacturing male workers of both private and public sectors are selected for analysis. Due to the fact that most female workers’ occupations in manufacturing are of clerks or servicemen that the technical level is not easy to identify, plus the existence of serve selectivity problem of adult female (Heckman, 1979), we focus on

2 Household member aged over 15 is counted as a civilian and is entitled a sample observation.
male wage structure at this study.

Given the micro data of wages and workers’ characteristics, we need industrial level data of trade, outward investment and R&D for empirical estimates. Trade data are collected by Directorate General of Customs, Ministry of Finance. Trade data contain both imports and exports in annual basis. outward investment data are provided by Investment Commission, Ministry of Economic Affairs. R&D expenditures by industry measure is available at Indicators of Science and Technology of National Science Council.

One of the challenges of this study is data arrangement with regard to the linkage of industrial classification across various data sources. Firstly, MUS contain the information of individuals’ industrial classification according to the 7th edition of “Standard Industrial Classification of Republic of China” by DGBAS in which 24 manufacturing industries (two digit) are categorized. However, there are only 15 industrial classification in outward investment data from Investment Commission. To link the two types of classification, we exclude Tobacco and Other Manufacturing from the 24 industrial classification that can’t match with outward investment categories, and then merge the remaining 22 industries of trade into the 15 categories. They are food and beverage processing, textile, garment and footwear, leather and fur products, lumber and bamboo products, paper products and printing, rubber products, plastic products, non-metallic minerals, basic metal and metal products, machinery equipments, electronic and electric appliances, transport equipments and precision instruments.

In addition to the reduction of industry classification of wage data, categorizing import and export data into industrial classification is not an easy task. Since trade data are collected by the customhouse on the basis of tariffs, all import and export items are classified by CCC or SITC codes that do not directly correspond to industrial categories. Fortunately, the Ministry of Finance supported a research project conducted by Taiwan Institute of Economic
Research that tried to classify the codes of imports and exports into standard industrial categories of manufacturing (Gong et al., 2004). Benefited from the research project, we applied the computer program developed by Gong et al. (2004) to convert the trade data (with 200,000 some observations annually) into 24 manufacturing industries, and then further condensed to be 15 ones. After the merging process, the dataset combined individual and industrial data are ready for empirical estimates. Appendix 1 is the matching table of the two types of industrial classification.

Table 1 shows the degree of globalization of Taiwan manufacturing toward three groups of countries defined by relative stages of development (per-capita GDP level) in comparison with that of Taiwan. They are OECD countries and countries in Asia with per-capita GDP above Taiwan (including Japan, Korea, Singapore), non-OECD countries and countries of per-capita GDP below Taiwan (including India, Indonesia, Malaysia, Myanmar, Philippines, Thailand, Vietnam), and China. These globalization index are measured in real term and counted as ratio of GDP of each industry. First row is average GDP of the 15 industries which increased substantially over the 6 years except for the year of 2001.\(^4\) With regard to imports and exports, the major trade partners of Taiwan are OECD and higher-developed Asian countries with industrial average ratio of import and export over GDP at around 40% to 60%. The weights of trading with non-OECD and Asian lower developed countries increased over time as import ratio grows from 8% to 13% and export ratio, 11% to 19%. With no doubt China is the single country which plays an important role in Taiwan’s internationalization. The industrial average ratio of import from China over GDP grows from 5% to 20% with 4 times growth, and ratio of export, from 2% to 36% with 18 times growth.

In terms of outward investment, capital movement toward OECD or non-OECD countries is limited that account for less than 0.5% of each industry’s GDP in average. In contrast, Taiwan’s outward investment toward China is evident as the industrial average ratio

\(^4\) 2001 is the only year that Taiwan’s GDP growth rate is negative over the past 50 years.
of outward investment over GDP increased from 1.24 in 1999 to 7.85 in 2004, peaked at 12% in 2003. Ratio of R&D over GDP is stable over the period at around 0.8%. Figure 1 shows that China alone is the single largest destination that Taiwan’s FDI heads toward. However, it is worth to note that the official measures of trade and outward investment China tends to be under estimated (Wang, 2001).

Table 3 shows the ratio of R&D over GDP across the industries over the years. Most industries spend limited ratio of their GDP for the expense of R&D. It is clear in Figure 2 that the industries of precision instrument, electronic and electric, transportation and chemicals rank the top four industries spending the largest amount of GDP ratio in R&D.

4. Empirical Results

Based on the combined data which is merged from various sources, we are able to estimate wage equations by taking worker’s characteristics and industrial openness into consideration at the same time. We use STATA 9.0 computer package to estimate quantile regression models. Because an OLS regression may shed no light on the conditional distribution of the dependent variable at various quantiles, this study employs quantile regression to delineate the conditional distribution of wage in depth with respect to openness. The wage equation is estimated by conditional quantile regression at every 5 percentiles, from the 5th to the 95th and with 19 regressions in total. We select three quartiles (the 25th, the 50th and the 75th quantiles) and the 10th and the 90th quantiles at the lower and upper tails as representatives. The estimated coefficients with test statistics of significance based on the bootstrapped standard errors are presented in Table 2. The results of mean (OLS) regression are also reported for comparison.

In the wage equation, dependent variable is logarithm of hourly wage, covariates include standard human capital variables, including education and age, and indexes of internationalization such as trade (net trade, imports and exports), FDI, and the interaction of
R&D and FDI. Since the complete dataset in estimation combined observations of 6 years, there are 5 year dummies included in the model. We have tried several model specification to test the robustness of the marginal effects of openness variables, therefore, covariates are varying in accordance with different setups.

Since quantile regression produces one more dimension of results than OLS, we report only the estimated results by graphs. Each plot in the following describes one covariate’s coefficient in the regression. The solid line with filled squares depicts the nineteen point estimates over the distribution of every five percentiles with the two solid lines side by side representing the upper and lower bounds of the 95% confidence intervals. The dashed horizontal line is the OLS estimate of the mean saver, and the area between the two dotted lines indicates its 95% confidence interval correspondingly.

Figure 3 presents a compact summary of the estimation of the marginal effects of net trade on wage. It is clear that net trade with China lifts wage level at almost the overall range of wage. It implies that net trade with China benefits workers at most unskilled and skilled level. Net export to OECD countries benefits low skilled workers more than high skilled counterpart that is consistent with H-O-S model. However, net trade with non-OECD countries has no effects on wage.

Since net trade is the trade volume of export netting out import, the individual effects of export and import in the wage equation might be contaminated by the tradeoffs between the two. In order to separate the effect of export from import, we then include imports and exports of GDP ratios in the model. The results are shown in Figure 4. Under the separate control of imports and exports, the result shows that imports from China has no effects on wage while exports to China benefits most wages of all skill level. The effects of imports from and exports to OECD countries on wages are resembling to that of trading with China. Furthermore, trades with non-OECD countries consistently brought negative effects on wages across the distribution. These results evidently reject the hypothesis that the effects of imports
and exports on wages are of opposite sign but similar magnitude. It implies that the aggregate
data analysis is possible subject to misspecification of the model.

Other than imports and exports, FDI is another important indicator of
internationalization. We therefore add FDI into the model with an interaction term of FDI and
R&D due to the reason of highly correlation between FDI and R&D. Economic meaning of
the interaction term is of two fold. One the one hand, if for certain industries that R&D
accounts for small fraction, such as food and beverage, then most of the effects of openness
will be attributed to FDI only. On the other hand, if for certain industries the R&D is very
important, such as high technological electronic and electrics, the effect of openness would
have to account for both FDI and the additional side effects accompanying R&D.

With 6 years data in an estimation, Figure 5 shows that imports plays no role in wage
setting while export to China favors wages at all level of skills except the top and bottom
quantiles. Effect of FDI to China alone is negative across the whole distribution of wages
while the reverse is true for the interaction term of FDI and R&D. It is suggested that for
low-tech industries FDI to China harms the wage at all levels. If the capital outward industries
have invested enough ratio of R&D over GDP, then the positive effects of R&D give fixed
FDI will outweigh the negative effect of FDI.

Since the industrial structure of Taiwan has been changing very fast over the past decade,
we then further stratify the 6 years data to be two equal parts, 1999-2001 and 2002-2004, to
check the possible structure change in terms of the relationship between openness and wage.
Figure 6 and 7 are for the two parts of data, respectively. Figure 6 shows that in 1999-2001,
imports from China brought positive effect on wage, the higher skill level the larger effect is.
In 2002-2004, imports from China seem to be negative to Taiwan’s wage, especially for the
wage below the first quartile. It implies that the effect of import from China has shift down in
parallel to change sign. Import from China was complement to Taiwan’s workers by 2001,
then the imports turn out to be competitive to domestic workers.
Export to China shows negative effect on wage under the first quartile in the first 3 years data and the reverse is true for the late 3 years data with the positive association of the effect and wage level. It suggests that the effect of export to China on wage has shift up evenly as the result of complementary effect of export to China.

In 1999-2001, FDI to China shows various effect on wage as low skilled is negative while high skilled is positive. If R&D is added into consideration the effect will be reverse that low skilled is positive but high skilled, negative. To discuss the two effect at a time, for a low-tech industry, FDI will be favorable to high-skilled wage but harmful to low skilled. For a high-tech industry with a lot of R&D, FDI will be not necessary unfavorable to low skilled, neither does the high-skilled wage will be favorable. It implies that there are two effects, complement and substitute, exist in the cross-straight FDI that varies across the wage distribution.

For the recent 3 years period, interaction term of FDI and R&D show no significant effect on wage. In the subsample, direct effect of FDI and R&D plays no significant role will be unfavorable to wages over last quartile. Similarly, over this period, FDI on OECD will cause the negative effects on low skilled while high skilled shows no effect. FDI to non-OECD shows negative effects on the overall wage distribution. The results reveal that some effects would have been changing over time. According to the merge and separate of overall data, some effects may cancel out each other and it has to be cautious to explain the above result.

5. Concluding Remarks

Although the theoretical models such as H-O-S and Mundell (1957) have provided precise predictions with regard to the impacts of internationalization on relative wages between countries of various development stages. Empirical studies on the related issues, however, seldom focus on the specific impacts of openness across the distribution of wage.
This study adds a new dimension to the literature by incorporating individual wage data and industrial openness indicators into estimation to derive insightful results. It is suggested that macro aspect “wage ratio” equation can’t exactly reveal the effects of internationalization on wage inequality. Furthermore, the ignorance of outward investment on wage equation is possible to subject to missing variable problem. To understand the complete effects of globalization on wage inequality, it is suggested to consider import, export and outward investment specifically at a time with the stratifications of types of partner countries. Future studies can be extended to include more covariates of both micro and macro data sources to have a more complete description of wage structure under the process of globalization.
## Appendix 1: Matching Standard Industrial Classification of Manufacturing with Outward Investment Classification

<table>
<thead>
<tr>
<th>Standard Industrial Classification, R.O.C.(^a) 7th revision edition, DGBAS, Executive Yuan</th>
<th>Approved Outward Investment by Industry Investment commission, Ministry of Economic Affairs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Food and kindred products</td>
<td>1. Food and beverage processing</td>
</tr>
<tr>
<td>2. Textile mill products</td>
<td>2. Textile</td>
</tr>
<tr>
<td>3. Apparel and textile products</td>
<td>3. Garment and footwear</td>
</tr>
<tr>
<td>4. Leather, furt and related products</td>
<td>4. Leather and fur products</td>
</tr>
<tr>
<td>5. Wood and bamboo products</td>
<td>5. Lumber and bamboo products</td>
</tr>
<tr>
<td>6. Furniture and fixture products</td>
<td></td>
</tr>
<tr>
<td>7. Pulp and paper products</td>
<td>6. Paper products and printing</td>
</tr>
<tr>
<td>8. Printing and kindred products</td>
<td></td>
</tr>
<tr>
<td>9. Industrial chemicals</td>
<td>7. Chemicals</td>
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<td>10. Chemical products</td>
<td></td>
</tr>
<tr>
<td>11. Petroleum and coal products</td>
<td></td>
</tr>
<tr>
<td>12. Robber products</td>
<td>8. Rubber products</td>
</tr>
<tr>
<td>15. Basic metal</td>
<td>11. Basic metals and metal products</td>
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<tr>
<td>16. Fabricated metal products</td>
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<tr>
<td>17. Machinery and equipment</td>
<td>12. Machinery equipment</td>
</tr>
<tr>
<td>19. Electrical and electronic machinery</td>
<td></td>
</tr>
<tr>
<td>20. Electrical machinery and equipment manufacturing</td>
<td></td>
</tr>
<tr>
<td>21. Transportation equipment</td>
<td>14. Transport equipment</td>
</tr>
<tr>
<td>22. Precision, optical and medical machinery</td>
<td>15. Precision instrument</td>
</tr>
</tbody>
</table>

Notes: a. The category is designed by the Executive Yuan, contains 24 types of manufacturing. Tobacco and miscellaneous are excluded since there is no corresponding manufacturing at FDI category.
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Tsou, Meng-Wen

Wang, S-Y

Wood, Adrian
Table 1: Degree of Globalization of Taiwan Manufacturing toward three groups, by country groups

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<tr>
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<tbody>
<tr>
<td><strong>Industrial Characteristics</strong></td>
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<td></td>
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<td></td>
<td></td>
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<td>GDP (million NT)</td>
<td>158045.3</td>
<td>161165.4</td>
<td>170379.8</td>
<td>191104.1</td>
<td>159266.8</td>
<td>18655.4</td>
<td>172162.3</td>
<td>212991.3</td>
<td>182103.3</td>
<td>231836.1</td>
<td>199111.5</td>
<td>262010.9</td>
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<td>Import from China (%)</td>
<td>5.06</td>
<td>5.57</td>
<td>6.20</td>
<td>6.24</td>
<td>6.98</td>
<td>7.29</td>
<td>9.56</td>
<td>10.87</td>
<td>14.24</td>
<td>16.30</td>
<td>19.92</td>
<td>21.15</td>
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<td>Export to China (%)</td>
<td>2.33</td>
<td>1.85</td>
<td>3.55</td>
<td>3.18</td>
<td>4.95</td>
<td>4.03</td>
<td>8.80</td>
<td>6.99</td>
<td>23.98</td>
<td>24.76</td>
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<td>Import from OECD (%)</td>
<td>40.37</td>
<td>40.22</td>
<td>47.21</td>
<td>48.76</td>
<td>40.64</td>
<td>37.32</td>
<td>37.45</td>
<td>31.75</td>
<td>46.08</td>
<td>46.22</td>
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<td>Export to OECD (%)</td>
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<td>59.21</td>
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<td>51.97</td>
<td>61.00</td>
<td>47.54</td>
<td>55.91</td>
<td>41.47</td>
<td>54.26</td>
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<td>Import from non-OECD (%)</td>
<td>7.99</td>
<td>8.73</td>
<td>9.01</td>
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<td>10.89</td>
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<td>18.77</td>
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<td><strong>Industrial Ratio of Outward Investment (OI) over GDP, by country groups (%)</strong></td>
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<td>FDI to China (%)</td>
<td>1.24</td>
<td>0.69</td>
<td>1.96</td>
<td>1.73</td>
<td>3.60</td>
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<td>5.91</td>
<td>12.32</td>
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<td>5.05</td>
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<td>FDI to OECD (%)</td>
<td>0.15</td>
<td>0.51</td>
<td>0.13</td>
<td>0.27</td>
<td>0.19</td>
<td>0.57</td>
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<td>0.06</td>
<td>0.12</td>
<td>0.27</td>
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<td>FDI to non-OECD (%)</td>
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<td><strong>Industrial Ratio of R &amp; D over GDP (%)</strong></td>
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<tr>
<td>R &amp; D (%)</td>
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<td>0.64</td>
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<td>0.86</td>
<td>0.92</td>
<td>0.79</td>
<td>0.82</td>
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Sources: various data source, authors calculate.

Note: country groups defined by the relative level of per-capita GDP in comparison with Taiwan.
Table 2: FDI/GDP Ratios Across Industries

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<th>Industries</th>
<th>total</th>
<th>China</th>
<th>Asia-above</th>
<th>Asia-below</th>
<th>OECD</th>
<th>n-OECD</th>
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<td>1</td>
<td>22.266</td>
<td>20.452</td>
<td>0.012</td>
<td>0.953</td>
<td>0.003</td>
<td>0.845</td>
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<td>2</td>
<td>29.331</td>
<td>22.677</td>
<td>0.000</td>
<td>5.107</td>
<td>0.296</td>
<td>1.251</td>
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<tr>
<td>3</td>
<td>45.403</td>
<td>29.850</td>
<td>0.017</td>
<td>4.433</td>
<td>1.408</td>
<td>9.695</td>
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<td>4</td>
<td>56.142</td>
<td>40.483</td>
<td>0.081</td>
<td>5.615</td>
<td>0.050</td>
<td>9.913</td>
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<td>5</td>
<td>62.805</td>
<td>59.755</td>
<td>0.000</td>
<td>0.890</td>
<td>0.877</td>
<td>1.284</td>
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<td>6</td>
<td>28.501</td>
<td>28.372</td>
<td>0.016</td>
<td>0.072</td>
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<td>7</td>
<td>18.567</td>
<td>14.112</td>
<td>0.350</td>
<td>0.925</td>
<td>2.603</td>
<td>0.578</td>
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<td>8</td>
<td>50.081</td>
<td>46.404</td>
<td>0.000</td>
<td>0.073</td>
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<td>9</td>
<td>48.734</td>
<td>46.734</td>
<td>0.273</td>
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<td>0.841</td>
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<td>10</td>
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<td>0.839</td>
<td>0.296</td>
<td>0.073</td>
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<td>11</td>
<td>31.110</td>
<td>29.118</td>
<td>1.303</td>
<td>0.317</td>
<td>0.341</td>
<td>0.032</td>
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<tr>
<td>12</td>
<td>17.847</td>
<td>17.124</td>
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<td>0.066</td>
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<td>13</td>
<td>67.093</td>
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<td>8.585</td>
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<td>14</td>
<td>24.921</td>
<td>17.709</td>
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<td>15</td>
<td>63.829</td>
<td>56.386</td>
<td>0.970</td>
<td>1.971</td>
<td>3.557</td>
<td>0.944</td>
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Table 3: R&D over GDP Ratios Across Industries

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</thead>
<tbody>
<tr>
<td>1. Food &amp; Beverage</td>
<td>0.430</td>
<td>0.450</td>
<td>0.420</td>
<td>0.390</td>
<td>0.390</td>
<td>0.380</td>
<td>0.320</td>
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<tr>
<td>2. Textile</td>
<td>0.320</td>
<td>0.400</td>
<td>0.390</td>
<td>0.350</td>
<td>0.290</td>
<td>0.270</td>
<td>0.260</td>
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<tr>
<td>3. Garment and Footwear</td>
<td>0.300</td>
<td>0.160</td>
<td>0.150</td>
<td>0.150</td>
<td>0.180</td>
<td>0.170</td>
<td>0.120</td>
<td>0.100</td>
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<tr>
<td>4. Leather, Fur</td>
<td>0.610</td>
<td>1.210</td>
<td>0.930</td>
<td>1.110</td>
<td>0.940</td>
<td>1.300</td>
<td>1.300</td>
<td>1.210</td>
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<tr>
<td>5. Lumber &amp; Banboo</td>
<td>0.080</td>
<td>0.170</td>
<td>0.020</td>
<td>0.030</td>
<td>0.020</td>
<td>0.030</td>
<td>0.070</td>
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<tr>
<td>6. Paper and Print</td>
<td>0.200</td>
<td>0.220</td>
<td>0.387</td>
<td>0.135</td>
<td>0.183</td>
<td>0.180</td>
<td>0.115</td>
<td>0.130</td>
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<tr>
<td>8. Rubber</td>
<td>1.060</td>
<td>1.180</td>
<td>0.910</td>
<td>0.557</td>
<td>0.522</td>
<td>0.700</td>
<td>0.660</td>
<td>0.740</td>
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<tr>
<td>9. Plastic</td>
<td>0.780</td>
<td>0.900</td>
<td>0.910</td>
<td>0.590</td>
<td>0.602</td>
<td>0.570</td>
<td>0.530</td>
<td>0.410</td>
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<td>10. Non-metallic</td>
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<td>0.280</td>
<td>0.320</td>
<td>0.280</td>
<td>0.230</td>
<td>0.340</td>
<td>0.220</td>
<td>0.200</td>
</tr>
<tr>
<td>11. Basic Metals</td>
<td>0.270</td>
<td>0.340</td>
<td>0.185</td>
<td>0.176</td>
<td>0.203</td>
<td>0.210</td>
<td>0.210</td>
<td>0.180</td>
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<td>12. Machinery Equipment</td>
<td>0.790</td>
<td>0.670</td>
<td>0.691</td>
<td>0.620</td>
<td>0.670</td>
<td>0.770</td>
<td>0.780</td>
<td>0.620</td>
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<tr>
<td>15. Precision Instrument</td>
<td>1.750</td>
<td>2.290</td>
<td>1.310</td>
<td>1.546</td>
<td>2.402</td>
<td>2.680</td>
<td>3.010</td>
<td>2.650</td>
</tr>
</tbody>
</table>
Figure 1: R&D / GDP Ratios Across Industries

Figure 2: Food & Beverage, Textile, Garment and Footwear, Leather, Fur, Lumber & Bamboo, Paper and Print, Chemicals, Rubber, Plastic, Non-metallic, Basic Metals, Machinery Equipment, Electronic and Electric, Transport Equipment, Precision Instrument
Figure 3  Net trade effects on wages
Figure 4  Import and export effects on wages
Figure 5 Internationalization and wage level, 1999-2004
Figure 6 Internationalization and wage level, 1999-2001
Figure 6 Internationalization and wage level, 2002-200