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Labor Market Effects of International Trade and Technological Change

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ABSTRACT

This paper addresses the effects of import competition and technological change on the earnings and employment of manufacturing workers in the United States. A two-stage least square (2SLS) method is used to estimate regression equations that determine: imports relative to total trade, payments of production relative to non-production workers, and R&D expenditure relative to total sales or investments in computers per worker. Unlike the estimates of previous studies, an estimate of the effect of technological change on the payments ratio is positive and significant. Similar to existing studies (using skilled versus unskilled workers), we find support for complementarity between capital and nonproduction workers. In addition, the effect of import share on technological change is negative, implying that import competition discourages investment in technological change among U.S. firms.

JEL classifications: F14, F16, J31.

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The U.S. wage inequality between skilled and unskilled workers has been increasing in recent decades. In most studies, technological change is regarded as the dominant factor (e.g. Lawrence and Slaughter (1993); Berman, Bound, and Griliches (1994)). A few trade economists argue that international trade or other forms of globalization has contributed substantially to the increase in wage inequality (Leamer (1994); Wood (1995); Feenstra and Hanson (1996)). Recent studies focus on how to measure technological change to assess the effect of technological change on wages (e.g. DiNardo and Pischke (1997); Autor, Katz and Krueger (1998)).

Three issues remain unsolved in the previous studies comparing the effects of international trade and technological change. First, these studies assume that the two factors are exogenous. If they are endogenous, however, the existing estimated effects are biased. One possibility is that after cheap imports invade the U.S. market U.S. firms may increase their investments for technological change to be competitive. This problem has been recognized in a few studies (e.g. Richardson (1995)), but little remedy has been offered.

There are two notable exceptions. Feenstra and Hanson (1999) estimate the effects of foreign outsourcing on nonproduction workers' relative payments, taking the endogeneity between technological change and product prices into account. Their estimated effects of outsourcing and computers are higher than those in other studies. Robertson (2000) examines the effect of globalization of the Mexican economy on nonproduction workers' relative wages in Mexico with considering the endogeneity between globalization and technological change. He finds that the globalization has increased nonproduction workers' relative wages.

Second, most previous studies do not take into account the effect of market structure on the impacts of import competition and technological change. Borjas and Ramey (1994) argue that industries suffering foreign competition such as steel and automobile have been highly concentrated and also paid relatively a lot to unskilled workers. They find negative relations between college wage premium and market concentration.

Finally, international economists have used the Heckscher-Ohlin-Samuelson (HOS) model to describe the effect of trade on factor prices. However, the assumptions in the HOS model, especially the exogeneity of technological change, if any, are not plausible for many U.S. manufacturing industries. Thus, the HOS model must be extended to allow for endogenous technological change. Feenstra and Hanson (1999) is an exception.

This paper tries to address these unsolved issues by estimating import, wage, and technological change equations simultaneously by two-stage least squares (2SLS). The measure of wage inequality used is a ratio of total payments of production workers to those of nonproduction workers from NBER Productivity Database. Nonproduction/Production worker classification has been used in many studies as skilled/unskilled worker distinction. Also, this paper constructs the source-weighted industry exchange rate introduced by Revenga (1992). This variable serves as proxy for the world price in the import equation and explains the industry variation in the import penetration well.

1 Structural Form of Trade, Relative Payment, and Technological Change Equations

The following structural equations aim to assess the effects of international trade and technological change on employment and wages in U.S. manufacturing industries. To take into account the endogeneity between these two factors, they must be treated endogenous variables in this system. The signs in parentheses indicate hypotheses about the variables discussed below.

(1) [Import Share]

$$IMPT = \alpha_1 + \alpha_2 \underset{(+)}{\frac{UNSKILL}{SKILL}} + \alpha_3 \underset{(-)}{TECH} + \alpha_4 \underset{(-)}{WP} + \varepsilon_1,$$

(2) [Payment Ratio]

$$\frac{UNSKILL}{SKILL} = \beta_1 + \beta_2 \underset{(-)}{IMPT} + \beta_3 \underset{(-)}{TECH} + \beta_4 \underset{(-)}{\log(KY)} + \beta_5 \underset{(+/-)}{\log(Y)} + \varepsilon_2,$$

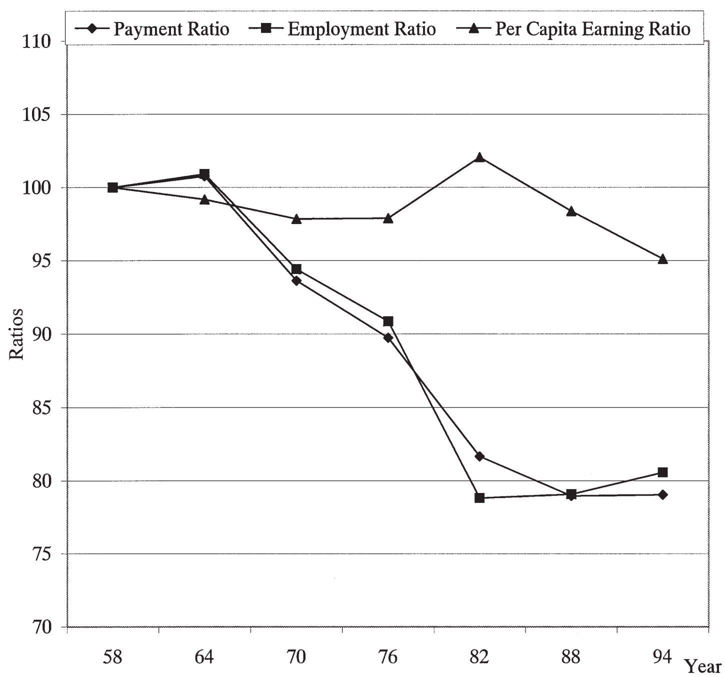
(3) [Technological Change]

$$TECH = \gamma_1 + \gamma_2 \underset{(+/-)}{IMPT} + \gamma_3 \underset{(-)}{\frac{UNSKILL}{SKILL}} + \gamma_4 \underset{(+/-)}{\log(Y)} + \gamma_5 \underset{(+/-)}{CR} + \varepsilon_3,$$

where $IMPT$ is the ratio of imports to total trade (imports+exports), $\frac{UNSKILL}{SKILL}$ is the relative payments of production workers, $TECH$ is technological change, WP is the world price, Y is the real output, KY is the capital-output Ratio, and CR is the market concentration.

IMPT measures import penetration into the U.S. market. It increases as imports increase for a given amount of exports. Thus, *IMPT* captures only interindustry import penetration. Below, I discuss a potential problem with intraindustry trade. Another possible measure is the ratio of import to domestic shipment (Feenstra and Hanson (1996)), although the use of this measure does not change our main results.

$\frac{UNSKILL}{SKILL}$ is an indicator of wage inequality. Because the total payments are the product of the wage paid and the number of units of labor hired, changes in the ratio could be due to changes in either factor. However, the relative per capita earning among manufacturing industries are similar. Figure 1 shows the time series of the averages of the payment ratio, employment ratio, and annual per capita earning ratio among SIC four-digit manufacturing industries from 1958 to 1994. The average of the per capita earning ratio across industries has been stable at 0.6. Moreover, the standard errors of the average are small for all years (not reported here). The averages of the employment ratio and the payment ratio across industries have been declining, except for the employment ratio in the 1980s. Figure 1 implies that changes in the relative payments stem mainly from changes



Changes in Averages of Payment, Employment, and Per Capita Earnings Ratios, 1958- 1994.

Ratio	1958- 64	1964- 70	1970- 76	1976- 82	1982- 88	1988- 94	1958- 94
Payment	0.74809	- 7.11888	- 3.89445	- 8.07545	- 2.70544	0.08484	- 20.9613
Employment	0.89979	- 6.49568	- 3.5433	- 12.0573	0.26041	1.49637	- 19.4397
Per Capita Earning	- 0.83118	- 1.33706	0.0595	4.1569	- 3.67638	- 3.24726	- 4.87548

Figure 1 Payment, Employment, and Per Capita Earnings Ratios (Production Worker/Nonproduction Workers): Averages of 450 U.S. Manufacturing Industries from 1958 to 1994 (1958=100).

in employment. However, it is not certain that the effects of international trade and technological change on payment and employment are identical. So this problem is discussed in Section 4 with estimates.

The data used for $TECH$ and WP are discussed in the next section. The real value of shipments is used as Y. The concentration ratio serves as indicator of CR.

(I) Hypothesis about the Import Share Equation

The first equation estimates $IMPT$. The coefficient for $\frac{UNSKILL}{SKILL}$ should be positive. According to factor-endowment trade models, a country exports goods that relatively intensively use the country's relatively abundant factor. The U.S. is generally considered to be human capital, i. e. nonproduction workers, abundant. Relative abundance in physical capital strengthens this, provided by capital-skill complementarity (Berman, Bound, and Griliches (1994)). Thus, the U.S. should export goods that relatively intensively use nonproduction workers. Stern and Maskus (1981) show the positive effect of human capital intensity on U.S. net exports from 1958 to 1976.

Further advanced models, such as the HOS model aims to explain interindustry trade. Yet, the volume of international trade between U.S. and other developed countries is huge. The HOS model cannot explain such intraindustry trade, which stem instead from imperfect competition. As discussed above, changes in $IMPT$ captures only changes in interindustry import penetration, to emphasize the portion of imports that could induce changes in relative factor prices.

Another problem with the HOS model is that its strong predictions on the change in relative factor prices hold only for the case of two factors and two goods. Xu (1993) has shown in a model of two factors and many goods that the predictions by the HOS model hold. Here we have three production factors: skilled workers, unskilled workers, and physical capital. The specific-factors model helps reduce the three factors to two in the short-run (Mayer (1974)). Suppose that there are two groups of industries, one that uses only unskilled labor and capital and the other that uses only skilled labor and capital. The former group can be thought of as low-tech industries and the latter as high-tech industries. The important assumption of the specific-factors model is that in the short-run, one factor specific to each industry is immobile. Here, the specific factor to low-tech industries is unskilled labor and that to high-tech industries is skilled labor. Further, assume that high-tech industries are not just skilled labor but capital intensive. When the relative price of the product of high-tech industries rises, wages of skilled labor increases while wages of unskilled labor decreases in the short run. In the long run, either kind of labor is mobile, and wages of both kinds of labor drop while the rental rate of capital goes up.

Finally, the factor endowment trade theory shows the effect of "relative factor endowment" on the international trade. Thus the ratio of production to nonproduction worker employment should be used. However, because of small and stable variation of the per capita earning ratio across industries, we replace the employment ratio with the payment ratio.

Technological change makes U.S. companies more competitive and results in either an increase in exports or a decrease in imports, so the coefficient for *TECH* should be negative. This follows from the Ricardian model. An increase in world price of a good makes its imports less attractive for U.S. consumers. Thus, *WP* has a negative effect.

(II) Hypothesis about Payment Ratio Equation

The second equation defines $\frac{UNSKILL}{SKILL}$. If the production workers' share to total payments is used, this equation is called share equation. Assuming a translog cost function, the share equation is derived from the first order condition of the cost minimization. Adding the technological change variable to the share equation is justified if a Hicks-Neutral technological change is assumed (Harrigan (1997)). One advantage of the payment ratio is that it can be decomposed into the per capita earning ratio and the employment ratio.

The argument that import competition has decreased both relative wages and employment of unskilled workers predicts that the coefficient for *IMPT* be negative. According to the Stolper-Samuelson theorem, an increase in interindustry trade could cause a reduction in the relative wage of production workers.

It is often argued that skilled-worker-biased technological change is the cause of the increase in wage inequality between skilled and unskilled workers. Assuming that *TECH* captures such biased technological change the coefficient for *TECH* is predicted to be negative.

The coefficient for $\log(KY)$ should be negative if capital-skill complementarity holds. The sign of the coefficient in the nonproduction workers' share equation of Berman, Bound, and Griliches (1994) is positive, which they argue implies such complementarity.

(III) Hypothesis about Technological Change Equation

The last equation defines *TECH*. The coefficient for *IMPT* depends on whether R&D and other efforts for technological progress are "aggressive" or "submissive" in response to import penetration (Scherer and Huh (1992)). An aggressive response means that domestic firms increase R&D expenditures when imports invade the market. Wood (1995) calls it "defensive innovation" in the sense that technological change makes U.S. firms more competitive with foreign firms. Scherer and Huh (1992) use 1971–87 data for 308 U.S. firms and find that the reaction is submissive.

The coefficient for $\frac{UNSKILL}{SKILL}$ should be negative. An increase in this ratio implies a decrease in the relative payment of nonproduction workers, including scientists and engineers. For them such industries are less attractive, lowering technological progress in these industries. The effect of $\log(Y)$ on *TECH* should be positive due to the increase in return to R&D investment. Geroski (1990) argues that inclusion of market size variable in the regression of technological change is necessary because of its correlation with market concentration. However, the effect of *CR* on investment in R&D is ambiguous. Loury (1979) shows that overall R&D investments increase as the number of firms decreases. However, changing only the cost structure, Lee and Wilde (1980) reach the opposite conclusion.

2 Data

Shipments, employment, and payments of both production and nonproduction workers, and real capital stock of four-digit SIC manufacturing industries are from the NBER productivity database. Import and export data are from the NBER Trade Database. Both are available at the NBER web site, www.nber.org, and they cover 1958 to 1994. Because the capital stock variable is valued in 1987 dollars, we use CPI to adjust all other variables to 1987 dollars.

Technological change variables used are: (1) investment in computers available from the Census of Manufactures, and (2) the ratio of expenditures on R&D to total sales, collected by NSF. These measures capture the investment in technological change, not technological change itself. Although the data on TFP are available in the NBER productivity database, we do not use TFP here because it is a function of production factors, causing a possible bias. The data on investments in computers is available for

Table 1 Summary Statistics of the Averages of 438 Manufacturing Industries.

Variable/Year	1977	1982	1987	1992	1977-92
(1) Employment	41.53402	39.96096	39.54784	37.98265	40.32915
(2) Production	30.65982	27.73059	27.25148	26.01507	28.37444
(3) NonProduction	10.87420	12.23037	12.29636	11.96758	11.95471
(4) (2)/(3)	3.835078	3.330794	3.300260	3.203098	3.492845
(5) Payment	544.1304	767.5731	960.0064	1109.370	859.5622
(6) Production	352.8071	459.1950	561.8241	630.2066	512.7301
(7) Non-production	191.3233	308.3781	398.1822	479.1603	346.8321
(8) (6)/(7)	2.329049	2.089053	2.015953	1.889751	2.111304
(9) Earning Ratio (=(4)/(8))	0.640894	0.665424	0.648437	0.620007	0.641906
(10) Capital	2181.650	2516.300	2603.470	2754.410	2527.960
(11) RealShipment	5760.980	5221.580	5587.130	5501.220	5613.840
(12) Capital/Output	0.749636	0.627399	1.089505	0.743766	0.740638
(13) Import	230.1551	407.0556	811.0324	1048.980	633.5216
(14) Export	212.2512	380.5475	455.8192	853.5462	472.3448
(15) Import/Im+Ex	0.498849	0.504260	0.630868	0.530392	0.550049
(16) R&D/Sales	1.487680	1.796998	2.193394	1.892184	1.858379
(17) Investments in Computers	0.064469	0.114108	0.237994	0.260003	0.167988
(18) 4-firm Concentration Ratio	39.69937	39.68749	40.39582	41.33604	40.20386

Notes
a. The unit of employment is one thousand workers.
b. For payment, capital stock, shipment, imports, exports and investments in computers, the unit is one million dollars.
c. Capital stock, shipment and investments in computers are measured in 1987 dollars.
d. 12 industries with either no imports or no exports during the sample period are excluded.

1977, 1982, 1987, and 1992 for SIC four-digit industries. While the R&D data have longer sample periods, it is available only for broader categories.

As the indicator of market concentration, we use the four-firm concentration ratio from the Census of Manufactures. These indices are available from 1954 to 1992.

As the proxies for WP, we use the import price indices available at the BLS web site, www.stats.bls.gov, and source-weighted industry exchange rates. There are two problems with the import price indices. These indices are not estimated for every four-digit SIC industry. Also, the sample period is short. The details of another proxy are discussed in the next section.

3 Estimated Results

In this section, we discuss the estimates of the model described in Section 1. In Subsection 3.1, estimates with import price indices are presented. As we show in Section

1, the variations in the payment ratio across industries are largely due to those of the employment ratio. To assess the difference of effects of international trade and technological change, in Subsection 3.2, we discuss the difference between the estimates with the payment ratio and those with the employment ratio. In Subsection 3.3, we present the estimates with the source-weighted industry exchange rates. They overcome the most problems with import price indices.

3.1 Estimates with Import Price Indices

Tables 2 show the OLS and the 2SLS estimates of the model equations. For the OLS estimates, each equation is estimated separately. The sample covers 1982 to 1992 for 21 industries, which is a balanced panel in terms of years and industries, thereby eliminating any econometric problems with an unbalanced panel. Year and industry fixed effects are controlled so that each of estimated coefficients purely reflects the industry variation in the effect of the factor. Also, to take the effect of industry size into account, all variables are weighted by the industry employment in 1982. Berman, Bound, and Griliches (1994) and Feenstra and Hanson (1996) use average shares of payments as weights to estimate the equation of the payment share of nonproduction workers. Finally, to increase the number of samples, we interpolate the missing values of three variables estimated every five years or selected years (two measures of technological change and the concentration ratio) linearly.

(I) Import Share Equations

In equation (1), the effect of $\frac{UNSKILL}{SKILL}$ is negative, unlike the HOS model suggests, although they are not statistically significant. The effects of *TECH* are positive, not significant though, contrary to the suggestion of the Ricardian model. we expect that an increase in import prices decreases the demand for the imports, but the coefficient for *WP* (demeaned by all year average for standardization and inflation-adjusted by CPI) is mixed and also not significant. To control for a possible nonlinear effect of *WP*, the squared import price index is added. In addition to this specification, we estimate the equation including one-year lagged independent variables (not reported here). Although all lagged variables are statistically significant, the effects are dissipated when they are used with contemporaneous independent variables. The other two equations have the same tendency,

Table 2-1 Estimates of the Import Share, Payment Ratio, and Technological Change Equations. World Price=Inflation-Adjusted Import Price Index. Technology=Research and Development/Total Sales Ratio.

Estimation Method	(a) OLS			(b) 2SLS		
Independent/Dependent Variables	(1) Import Share	(2) Payment Ratio	(3) R&D/ Sales Ratio	(4) Import Share	(5) Payment Ratio	(6) R&D/ Sales Ratio
Intercept	0.000 (0.005)	0.000 (0.015)	0.000 (0.015)	0.000 (0.005)	0.001 (0.018)	−0.001 (0.041)
Import Share		−0.483** (0.226)	0.406* (0.220)		−2.605** (0.919)	4.008 (4.288)
Payment Ratio (Unskill/Skill)	−0.029 (0.022)		0.039 (0.071)	−0.092 (0.070)		2.491* (1.493)
R&D/Sales Ratio	0.043* (0.022)	−0.058 (0.081)		−0.040 (0.047)	−0.040 (0.390)	
Import Price Index	0.001 (0.001)			−0.001 (0.001)		
Import Price Index-Squared	0.00007** (0.00002)			0.00005* (0.00003)		
Log (Capital/Output Ratio)		−0.162 (0.128)			−0.090 (0.345)	
Log (Price-Adjusted Shipment)		0.592* (0.308)	−1.544** (0.213)		0.804 (0.940)	−3.965** (1.616)
Concentration Ratio			−0.024** (0.004)			−0.038** (0.014)
Adjusted R-squared	0.331	0.231	0.529	0.294	0.167	0.091
F-value in the 1st stage				4.654**	8.847**	32.359**

Notes
a. Balanced panel data: 11 years (1982 to 92) and 21 industries.
b. All variables are weighted by industry employment in 1982.
c. Shipment and Import Price Index are adjusted by CPI.
d. Real Shipment is its log-value.
e. Import Price Index is demeaned by all-year average.
f. Standard errors are in parentheses.
g. Year and Industry Fixed Effects are controlled
h. *Statistically significant at the .10 level, **at the .05 level.

which implies the time lag is not critical in this estimation.

Equation (4) is estimated by 2SLS, allowing for the endogeneity of *IMPT* with $\frac{UNSKILL}{SKILL}$ and *TECH*. The signs are more similar to those predicted, but all effects are insignificant.

(II) Payment Ratio Equations

As predict, in equation (2) the effect of *IMPT* is negative and significant. The next important finding concerns the effect of *TECH* (equation (5) of Table 2−2). By OLS, we obtained the expected sign (negative). By calculating the elasticities at the averages of $\frac{UNSKILL}{SKILL}$, *IMPT*, and *TECH* (real investments in computers per worker), we find that the effect of *TECH* is far greater than the effect of *IMPT* (−3.16 over −0.74). This is

Table 2-2 Estimates of the Import Share, Payment Ratio, and Technological Change Equations. World Price = Inflation-Adjusted Import Price Index. Technology = Real Investments in Computers per Worker.

Estimation Method	(a) OLS			(b) 2SLS		
Independent/Dependent Variables	(1) Import Share	(2) Payment Ratio	(3) Investment in Computer	(4) Import Share	(5) Payment Ratio	(6) Investment in Computer
Intercept	0.000 (0.005)	0.000 (0.015)	0.000 (0.003)	0.000 (0.009)	0.000 (0.032)	0.000 (0.003)
Import Share		−0.478** (0.219)	0.031 (0.042)		−2.457 (1.613)	0.009 (0.295)
Payment Ratio (Unskill/Skill)	−0.034 (0.022)		−0.037** (0.014)	−0.106 (0.119)		−0.023 (0.103)
Real Investment in Computer per Worker	0.061 (0.121)	−0.902** (0.371)		−2.740 (2.115)	8.479 (12.700)	
Import Price Index	−0.000 (0.001)			0.000 (0.001)		
Import Price Index-Squared	0.00006** (0.00002)			0.000 (0.000)		
Log (Capital/Output Ratio)		−0.094 (0.108)			−0.253 (0.376)	
Log (Price-Adjusted Shipment)		0.708** (0.243)	−0.002 (0.041)		1.039* (0.576)	−0.014 (0.111)
Concentration Ratio			0.001 (0.001)			0.001 (0.001)
Adjusted R-squared	0.319	0.251	0.386	0.073	0.022	0.368
F-value in the 1st stage				3.641**	9.196**	1.461

Notes
a. Balanced panel data: 11 years (1982 to 92) and 21 industries.
b. All variables are weighted by industry employment in 1982.
c. Shipment and Import Price Index are adjusted by CPI.
d. Real Shipment is its log-value.
e. Import Price Index is demeaned by all-year average.
f. Standard errors are in parentheses.
g. Year and Industry Fixed Effects are controlled
h. *Statistically significant at the .10 level, **at the .05 level.

consistent with the most previous studies. However using 2SLS, the coefficient becomes positive and insignificant. Finally, the sign of log (KY) is negative but insignificant, which weakly supports capital-skill complementarity.

(III) Technological Change Equations

In equations (3) and (6), the signs of the *IMPT* coefficients are positive, although not significant, so the defensive innovation is not clearly supported. $\frac{UNSKILL}{SKILL}$ has a significant negative effect with OLS in Table 2-2 while not significant with 2SLS. Y has a negative effect, not significant though in Table 2-2. Finally, *CR* has a significant negative effect with R&D/Total Sales ratio, while it has a positive effect with per-worker investments in computers.

3.2 Employment Ratio as Labor Market Variable

As shown in Section 1, compared to the employment ratio, annual per capita earning ratio has little variation across industries. If the effects on the employment ratio are the same as those on the payment ratio, only employment has been affected. A comparison of estimates with the payment ratio and those with the employment ratio (not reported here) does not give a clear conclusion: the signs of coefficients are similar, but the sizes are not. This finding may be due to variations of per-capita earning ratio across industries, or some measurement issue. In sum, we cannot say from this result that only relative employment has been affected.

3.3 Estimates with the Source-Weighted Industry Exchange Rate

As shown in Subsection 3.1, the import price index is not a good explanatory variable for *IMPT*. To fix this problem, we introduce source-weighted industry exchange rate, which is a weighted average of foreign exchange rates, using the shares of countries exporting the good to the U.S. as weights. Revenga (1992) argues that the import price index may be correlated with unobserved errors in the structural form of labor demand and supply equations, and uses the source-weighted industry exchange rate as an instrumental variable to estimate the effects of import prices on wages and employment. Here, we use the source-weighted industry exchange rate as an explanatory variable for *IMPT* to capture the variation in *WP* across industries.

3.3.1 Construction of the Source-Weighted Industry Exchange Rate

we calculate the weights of exporting countries for each SIC four-digit good by the following procedure. To our knowledge, there is no US trade statistics with quantity according to SIC, so we use SITC. Following Revenga (1992), we make a table of cross-classifications between Schedule A (basically parallel to SITC) and SIC, using Department of Commerce, *U.S. Foreign Trade Statistics, Classifications and Cross-classifications 1974*. Because Schedule A and SIC are not isomorphic, many SIC four-digit goods have more than one Schedule A good. Then, for each SIC four-digit good whose cross classification to Schedule A is possible, we calculate the weights of exporting countries for all Schedule A goods, using Department of Commerce, *U.S. Foreign Trade, Imports Commodity by Country, December 1972*. Finally, taking the weighted average of Schedule A goods, we get the weights of exporting countries for 114 SIC four-digit industries. The dollar values of imports are used as weights because different Schedule A goods corresponding to one SIC four-digit good may have different units of quantity.

Exchange rate data are IMF, *International Financial Statistics*. The unit of exchange rate is the units of the foreign currency per dollar, and there is huge variation in the nominal value of exchange rate across countries. We take the log, and subtract the all-year average from the logged exchange rate in each year. After this standardization, we take the weighted averages of exchange rates to get the source-weighted industry exchange rates.

3.3.2 Estimates

Tables 3 present the estimates. Both year and industry fixed effects are controlled. The sample covers 1977 to 1992 and 63 industries. It is not exactly a balanced panel because it includes important industries (auto and aircraft), which have some missing variables.

Tables 3 also show the statistics of Durbin-Wu-Hausman (DWH) test of endogeneity for *IMPT* and *TECH*. We perform two-step regressions to get the test statistics. First, we regress these variables separately on all exogenous variables to get residuals. Then we estimate the $\frac{UNSKILL}{SKILL}$ equation with the estimated residuals. Davidson and MacKinnon (1993) show that the DWH test statistic is equal to the F-value with the null hypothesis that

Table 3-1 Estimates of the Import Share, Payment Ratio, and Technological Change Equations. World Price=Source-Weighted Industry Exchange Rate. Technology=Research and Development/Total Sales Ratio.

Estimation Method	(a) OLS			(b) 2SLS		
Independent/Dependent Variables	(1) Import Share	(2) Payment Ratio	(3) R&D/ Sales Ratio	(4) Import Share	(5) Payment Ratio	(6) R&D/ Sales Ratio
Intercept	−0.000 (0.002)	0.000 (0.006)	0.000 (0.012)	−0.000 (0.003)	−0.000 (0.013)	−0.000 (0.017)
Import Share		0.051 (0.083)	0.090 (0.155)		−4.365 (6.329)	−5.243** (2.363)
Payment Ratio (Unskill/Skill)	0.017 (0.011)		−0.511** (0.054)	−0.007 (0.056)		−0.481 (0.322)
R&D/Sales Ratio	0.004844 (0.006561)	−0.153** (0.016)		−0.189** (0.080)	−0.462 (1.348)	
Industry Exchange Rate	0.0270** (0.011)			0.003 (0.018)		
Industry Exchange Rate Squared	−0.002 (0.007)			0.002 (0.010)		
Log (Capital/Output Ratio)		−0.409** (0.043)			−0.316 (0.333)	
Log (Price-Adjusted Shipment)		0.085* (0.049)	−0.106 (0.079)		0.247* (0.146)	0.123 (0.239)
Concentration Ratio			0.007** (0.003)			0.002 (0.005)
Adjusted R-squared	0.428	0.345	0.363	0.282	0.085	0.176
DWH Test				10.306**		2.326
F-value in the 1st stage				5.397**	81.870**	3.574**

Notes
a. Almost-balanced panel data: 16 years (1977 to 92) and 63 industries.
b. All variables are weighted by industry employment in 1977.
c. Shipment and Industry Exchange Rate are adjusted by CPI.
d. Real Shipment is its log-value.
e. Standard errors are in parentheses.
f. *Statistically significant at the .10 level, **at the .05 level.
g. Year and Industry Fixed Effects are controlled.

the coefficient for the residual is zero. Except for the R&D/Sales Ratio in Table 3-1, the hypothesis is rejected.

(I) Import Share Equations

The predicted sign of the source-weighted industry exchange rate is positive. For the *IMPT* equations (1) and (4), OLS gives desirable results in the sense of the signs of coefficients except for *TECH*. In Table 3-2, it is true even when we perform 2SLS, but not

Table 3-2 Estimates of the Import Share, Payment Ratio, and Technological Change Equations. World Price=Source-Weighted Industry Exchange Rate. Technology=Real Investments in Computers per Worker.

Estimation Method	(a) OLS			(b) 2SLS		
Independent/Dependent Variables	(1) Import Share	(2) Payment Ratio	(3) Investment in Computer	(4) Import Share	(5) Payment Ratio	(6) Investment in Computer
Intercept	−0.001 (0.003)	0.000 (0.007)	−0.004** (0.002)	0.001 (0.003)	0.003 (0.008)	−0.006 (0.005)
Import Share		0.028 (0.084)	0.016 (0.025)		−0.795 (0.936)	−1.625** (0.674)
Payment Ratio (Unskill/Skill)	0.013 (0.012)		−0.015* (0.009)	0.081* (0.042)		−0.241** (0.095)
Real Investment in Computer per Worker	0.060 (0.043)	0.013 (0.113)		0.474* (0.222)	1.500** (0.731)	
Industry Exchange Rate	0.025** (0.011)			0.031** (0.012)		
Industry Exchange Rate Squared	−0.004 (0.008)			−0.019* (0.011)		
Log (Capital/Output Ratio)		−0.403** (0.049)			−0.549** (0.090)	
Log (Price-Adjusted Shipment)		0.052 (0.054)	0.044** (0.013)		−0.063 (0.120)	0.187** (0.061)
Concentration Ratio			0.001** (0.0005)			−0.002 (0.002)
Adjusted R-squared	0.419	0.246	0.474	0.390	0.208	0.120
DWH Test				4.662**		6.426**
F-value in the 1st stage				4.902**	58.621**	8.352**

Notes
a. Almost-balanced panel data: 16 years (1977 to 92) and 63 industries.
b. All variables are weighted by industry employment in 1977.
c. Shipment and Industry Exchange Rate are adjusted by CPI.
d. Real Shipment is its log-value.
e. Standard errors are in parentheses.
f. *Statistically significant at the .10 level, **at the .05 level.
g. Year and Industry Fixed Effects are controlled.

in Table 3-1.

(II) Payment Ratio Equations

In the $\frac{UNSKILL}{SKILL}$ equations (2) and (5), we obtain predicted results. With OLS, except *TECH* in Table 3-2, the effect of *IMPT* is not significant while that of *TECH* is negative. With 2SLS, *IMPT* has negative effect, insignificant though, while *TECH* has positive or insignificant effect. Finally, the capital-skill complementarity holds with either ways of estimation.

(III) Technological Change Equations

In the *TECH* equations (3) and (6), the effect of *IMPT* is negative and statistically significant with 2SLS, suggesting that defensive innovation is not observed when we take endogeneity of *IMPT* and *TECH* into account. $\frac{UNSKILL}{SKILL}$ has negative effects in two out of four equations. Finally, the positive effects of *CR* and *Y* are found in most equations.

The summaries of the results are the following. First, the effect of *TECH* on $\frac{UNSKILL}{SKILL}$ is not either negative or significant with 2SLS. Second, the source-weighted industry exchange rate is a good explanatory variable for *IMPT*. Third, regardless of endogeneity problem, the capital-skill complementarity holds. Finally, the idea of defensive innovation is not supported.

4 Validity of Estimates

One issue of validity is about the estimation methods of simultaneous equations. In this paper I use 2SLS, but three-stage least squares (3SLS) and Full-information maximum likelihood (FIML) could be the options. One problem with these methods is that they are more sensitive to small sample bias than OLS and 2SLS. In this paper, the number of observation is 207 for the estimation with import price indices, and 1008 for the estimation with source-weighted industry exchange rates. The results with 3SLS and FIML bias are not reported, but the signs of estimates by 3SLS and FIML are almost the same as those by 2SLS.

There is another argument about the use of 2SLS. It is an instrumental variable (IV) estimation, so the validity of 2SLS estimates depends on the validity of instruments. Bound, Jaeger, and Baker (1995) argue that if an IV's correlation with the endogenous variable is weak, the bias of 2SLS is serious and the direction of 2SLS bias is same as that of OLS bias. To check the validity of an IV, They suggest looking at the F-value of the first stage estimation of 2SLS. The F-statistics are in the last rows of Tables 2 and 3, which reject the null hypotheses of zero coefficients for IVs except only for the equation (6) of Table 2-2.

In addition to this evidence, our justification for each of IVs is the following. About *WP*, the import price index may have a correlation with error term, as Revenga (1992) argues. But for source-weighted industry exchange rate, we believe that there is no serious problem as an IV. The Foreign Exchange Committee, New York Federal Reserve Bank, *1995 Annual Report* says that most of foreign exchange transactions are either interbank or interbroaker dealings. This suggests that the transactions of foreign exchange demanded by manufactures are relatively few.

To check the robustness of 2SLS and to show more evidence of validity of the source-weighted industry exchange rate, we perform the following two-step regression: (1) Regress *IMPT* on the industry exchange rate and its squared value. This gives a predicted value of *IMPT*. (2) Regress $\frac{UNSKILL}{SKILL}$ and *TECH* on the predicted *IMPT*. Both industry and year fixed effects are controlled, but the endogeneity between international trade and technological change is not. The results are as follows (standard errors are in parentheses). *Exchange* is the source-weighted industry exchange rate and *IMPT* is *IMPT* predicted in step one.

1. *TECH* = R&D/Sales Ratio.

[Step One] $IMPT = \underset{(0.002)}{0.000} + \underset{(0.011)}{0.026} \cdot Exchange - \underset{(0.007)}{0.001} \cdot Exchange^2$. Adjusted $R^2 = 0.427$.

[Step Two] $\frac{UNSKILL}{SKILL} = \underset{(0.010)}{0.000} - \underset{(1.234)}{2.349} \cdot IMPT$. Adjusted $R^2 = 0.096$.

$TECH = \underset{(0.016)}{0.000} - \underset{(2.110)}{4.139} \cdot IMPT$. Adjusted $R^2 = 0.197$.

2. *TECH* = Price-adjusted investments in computers per worker.

[Step One] $IMPT = \underset{(0.003)}{-0.001} + \underset{(0.011)}{0.024} \cdot Exchange - \underset{(0.007)}{0.001} \cdot Exchange^2$.

Adjusted $R^2 = 0.427$.

[Step Two] $\frac{UNSKILL}{SKILL} = \underset{(0.009)}{0.006} - \underset{(1.209)}{1.944} \cdot IMPT$. Adjusted $R^2 = 0.106$.

$TECH = \underset{(0.004)}{-0.007} - \underset{(0.619)}{1.560} \cdot IMPT$. Adjusted $R^2 = 0.139$.

This two-step regression shows that *Exchange* explains the import share well and the predicted *IMPT* clearly shows the negative significant effects on $\frac{UNSKILL}{SKILL}$ and *TECH*.

About the $\frac{UNSKILL}{SKILL}$ equation, all explanatory variables are derived from the first order condition. Thus, at least theoretically, there is no problem with IVs. About the *TECH* equation, *CR* could be endogenous (Koeller (1995)). But the measure suggested by Bound, Jaeger, and Baker (1995) implies that it is not a big problem with this estimation. There is an argument that technological change is due to the stock of the investments. If this is correct, capital/output ratio could be an explanatory variable for technological change. Although this is an interesting question, we do not use capital/output ratio in technological change equation partly because we use this variable for identification of $\frac{UNSKILL}{SKILL}$ equation and partly because the effect is not theoretically conclusive among various kinds of technological change.

5 Conclusions

This paper explores the effects of import penetration and technological change on wage differential between skilled and unskilled workers in the U.S. manufacturing industries with taking the endogeneity of these two factors into account. The estimated results suggest that contrary to the previous studies, the technological change is not a dominant cause of increase in wage differential when we take into account the endogeneity of import share and technological change by the 2SLS. My estimates support capital-skill complementarity, but not defensive innovation, described by the positive effect of import share on the investment for the technological change.

As discussed in Section 1, this paper focuses on interindustry import penetration. However, we should discuss other forms of globalization such as intraindustry import competition between the U.S. and other developed countries or foreign direct investment by U.S. firms to assess the effects of globalization and technological change on the U.S. labor market. Our study suggests that taking the endogeneity into account is worth trying even with other proxies of the globalization and technological change.

Finally, this study suggests a possible role of government's trade policy or subsidy for technological change to decrease the wage inequality among U.S. manufacturing workers. Either policy could mitigate import penetration, resulting in an increase in the relative payments of production workers through the mechanism discussed in this paper. A study with federal government's R&D subsidy or U.S. tariff data could be a possible extension of this study.

References

[1] Autor, David H., Lawrence F. Katz, and Alan B. Krueger. 1998. "Computing Inequality : Have Computers Changed the Labor Market ?" Quarterly Journal of Economics, Vol. 113, No. 4 (November), pp. 1169-1213.

[2] Berman, Eli, John Bound, and Zvi Griliches. 1994. "Changes in the Demand and for Skilled Labor within U.S. Manufacturing : Evidence from the Annual Survey of Manufactures." Quarterly Journal of Economics, Vol. 109, No. 2 (May), pp. 367-397.

[3] Borjas, George and Valerie Ramey. 1995. "Foreign Competition, Market Power, and Wage Inequality." Quarterly Journal of Economics, Vol. 110, No. 4 (November), pp. 1075-1110.

[4] Bound, John, David A. Jaeger, and Regina M. Baker. 1995. "Problems with Instrumental Variables Estimation when the Correlation between the Instruments and the Endogenous Explanatory Variable is Weak." Journal of the American Statistical Association, Vol. 90, No. 430 (June), pp. 443-450

[5] Davidson, Russell and James G. MacKinnon. 1993. Estimation and Inference in Econometrics. Oxford University Press.

[6] DeNardo, John E. and Jorn-Steffen Pischke. 1997. "The Return to Computer Use Revisited : Have Pencils Changed the Wage Structure too ?" Quarterly Journal of Economics, Vol. 112, No. 1 (February), pp. 291-304.

[7] Feenstra, Robert C. and Gordon H. Hanson. 1996. "Foreign Investment, Outsourcing, and Relative Wage." In Robert C. Feenstra, Gene M. Grossman, and Douglas A. Irwin, eds., The Political Economy of Trade Policy. MIT Press, pp. 89-128.

[8] Feenstra, Robert C. and Gordon H. Hanson. 1999. "The Impact of Outsourcing and High-Technology Capital on Wage : Estimates for the United States, 1979-1990." Quarterly Journal of Economics, Vol. 114, No. 3 (August), pp 907-940.

[9] Geroski, P. A. 1990. "Innovation, Technological Opportunity, and Market Structure." Oxford Economic Papers, Vol. 42, No. 3 (July), pp. 586-602.

[10] Harrigan, James. 1997. "Technology, Factor Supplies, and International Specialization : Estimating the Neoclassical Model." American Economic Review, Vol. 87, No. 4 (September), pp. 475-494.

[11] Koeller, C. Timothy. 1995. "Innovation, Market Structure, and Firm Size : a Simultaneous Equations Model." Managerial and Decision Economics, Vol. 16, No. 3 (May-June), pp. 259-269.

[12] Lawrence, Robert Z. and Matthew J. Slaughter. 1993. "International Trade and American Wages in the 1980s : Giant Sucking Sound or Small Hiccup." Brookings Papers on Economic Activities : Microeconomics 2, pp. 161-226.

[13] Leamer, Edward E. 1994. "Trade, Wages and Revolving Door Ideas." NBER Working Paper, No. 4716 (April).

[14] Lee, Tom and Louis L. Wilde. 1980. "Market Structure and Innovation : A Reformation." Quarterly Journal of Economics, Vol. 94, No. 1 (March), pp. 429-436.

[15] Loury, Glen C. 1979. "Market Structure and Innovation." Quarterly Journal of Economics, Vol. 93, No. 1 (February), pp. 395-410.

[16] Mayer, Wolfgang. 1974. "Short-Run and Long-Run Equilibrium for a Small Open Economy." Journal of Political Economy, Vol. 82, No. 5 (September/October), pp. 955-967.

[17] Revenga, Ana. 1992. "Exporting Jobs? The Impact of Import Competition on Employment and Wages in U.S. Manufacturing." Quarterly Journal of Economics, Vol. 107, No. 1 (February), pp. 255-284.

[18] Richardson, J. David. 1995. "Income Inequality and Trade: How to Think, What to Conclude." Journal of Economic Perspectives, Vol. 9, No. 2 (Summer), pp. 33-55.

[19] Robertson, Raymond. 2000. "Trade or Technology? Why Not Both? Evidence on Technology Choice, Wage Inequality, and International Trade." Unpublished Paper, Macalester College.

[20] Stern, Robert M. and Keith E. Maskus. 1981. "Determinants of the Structure of U.S. Foreign Trade, 1958-76." Journal of International Economics, Vol. 11, No. 2 (May), pp. 207-224.

[21] Scherer, F. M. and Kuen Huh. 1992. "R&D Reactions to High-Technology Import Competition." Review of Economics and Statistics, Vol. 74, No. 2 (May), pp. 202-212.

[22] Wood, Adrian. 1995. "How Trade Hurt Unskilled Workers." Journal of Economic Perspectives, Vol. 9, No. 2 (Summer), pp. 57-80.

[23] Xu, Yingfeng. 1993. "A General Model of Comparative Advantage with Two Factors and A Continuum of Goods." International Economic Review, Vol. 34, No. 2 (May), pp. 365-380.

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