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An empirical analysis based on microdata of the *Census of Manufactures*

FUKAO Kyoji
RIETI

ITO Keiko
Senshu University

RIETI
Research Institute of Economy, Trade & Industry, IAA
The Research Institute of Economy, Trade and Industry
http://www.rieti.go.jp/en/

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Output Quality, Skill Intensity, and Factor Contents of Trade: An empirical analysis based on microdata of the *Census of Manufactures*

Kyoji FUKAO (Hitotsubashi University and RIETI) *
Keiko ITO (Senshu University) **

Abstract

Using factory-level data for Japan's manufacturing sector, we estimate the relationship between the unit values of gross output and factor intensities. We find a significant and positive relationship between the unit value of a product and its white-collar labor intensity, which supports the assumption widely used in theoretical models that commodities with higher prices are of higher quality and more human capital-intensive. However, the relationship between the unit value of a product and its capital intensity is not always positive, and is significantly negative in some sectors.

Using the results of the relationship between unit values and factor intensities, we also estimate the factor contents of Japan's trade, taking account of differences in the unit values of exports and imports. We find that the number of non-production workers and the capital stock embodied in Japan's net exports are under-estimated when differences in unit values are not taken into account.

Key words: Vertical intra-industry trade, unit value, quality, factor intensity, factor contents of trade

JEL classification: F10, F12, F14

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* Corresponding author: Institute of Economic Research, Hitotsubashi University, 2-1, Naka, Kunitachi, Tokyo 186-8601 JAPAN. Tel: +82-42-580-8359, FAX.: +81-42-580-8333, e-mail: k.fukao@srv.cc.hit-u.ac.jp
** Faculty of Economics, Senshu University, 2-1-1, Higashi-Mita, Tama-ku, Kawasaki 214-8580 JAPAN. Tel.: +81-44-900-7818, Fax.: +81-44-911-0467, e-mail: keiko-i@isc.senshu-u.ac.jp.

1. Introduction

Recent studies on intra-industry trade (IIT) have brought to light rapid increases in vertical IIT (VIIT), i.e., intra-industry trade where goods are differentiated by quality. Falvey (1981) pointed out in his seminal theoretical paper that commodities of the same statistical group but of different quality may be produced using different mixes of factor inputs. Based on this idea, empirical studies have typically used information on the unit value of commodities as a proxy for product quality and, employing such unit value data, have examined patterns of IIT or the international division of labor (e.g., Greenaway et al., 1994, Fontagné et al., 1997). Research has also shown that developed economies tend to export commodities at higher prices than developing economies (e.g., Schott, 2004, Hummels and Klenow, 2005). These studies suggest that an increase in VIIT may have a large impact on factor demand and factor prices in both developed and developing countries if there exists a positive relationship between commodity prices or quality and physical and human capital-intensities. For example, Widell (2005), addressing this issue, calculated the factor contents of Swedish trade, adjusting for difference between export unit values and import unit values, and found that the average human capital content of Swedish exports was higher than that of imports, contradicting previous empirical results.[1]

On the other hand, many studies have investigated the impact of increasing imports from developing countries on developed countries, focusing on issues such as domestic skill-upgrading, capital deepening, firm dynamics, and so on (e.g., Feenstra and Hanson, 1999, 2001). Although such studies do not rely on unit value or price information, their ideas are founded on the assumption that developed economies export physical and human capital-intensive products of high quality and import unskilled labor-intensive products of low quality from developing economies. Thus, many theoretical and empirical studies have in common that they take the positive relationships between commodity prices or quality and physical and human capital-intensities as given. Yet, to the best of our knowledge, there are no studies that have empirically examined the relationship between unit values of commodities and their factor contents at the commodity level.

Against this background, in this study, using micro-data of the *Census of Manufactures* (CM) for Japan and comparing the factor inputs of factories producing the same goods, we estimate the relationship between the unit values of gross output and factor contents and test whether factories that produce goods with a higher unit value tend to input more skilled labor and capital stock services. To do so, we treat factories producing the same commodity according to detailed commodity classifications as producing the "same" goods. (Ideally, we should use information on factor intensities at the commodity level. However,

[1] There are an increasing number of studies which use unit value information as a proxy for product quality. For example, Baldwin and Harrigan (2007) find that export unit values are positively related to distance, which is consistent with the prediction of their quality heterogeneous-firms model where only firms with sufficiently high-price/high-quality goods find it worthwhile to export to distant markets. Meanwhile, Kugler and Verhoogen (2008), using data of Colombian manufacturing plants, find that output and input prices are positively correlated with plant size within industries and that exporters tend to have higher output and input prices. They interpret their results as implying that input quality and plant productivity are complementary in generating output quality. And Hallak and Sivadasan (2009), using manufacturing establishment data for India, the United States, Chile, and Colombia, show that conditional on size, exporters are likely to sell products of higher quality and at higher prices, pay higher wages, and use capital more intensively.

such information is not available, so that we use factory-level factor intensity information as a proxy for commodity-level factor intensity information.) Using the results of the relationship between unit values and factor intensity, we then estimate the factor contents of Japan's trade with the rest of the world. For the analysis, we use micro-data of the CM and Japanese trade statistics. Factor intensities such as capital-labor ratios and skilled-unskilled labor ratios are calculated at the 6-digit commodity-level using the micro-data of the CM, an establishment-level annual survey conducted by the Ministry of Economy, Trade and Industry. Commodity-level unit values for products made domestically are calculated using the micro-data of the CM, while unit values for exports and imports are calculated using Japan's Trade Statistics. Finally, using the estimated relationship between unit values and factor intensities and unit value data on Japan's international trade, we estimate the factor contents of Japan's exports and imports.

The remainder of the paper is organized as follows. In Section 2, we present a simple theoretical model for the estimation of the relationship between unit values and factor intensities. Next, in Section 3, we describe the data sources for our variables and how our dataset is constructed. In Section 4 we then provide econometric evidence on the relationship between output unit values and factor intensities, while in Section 5 we estimate the factor contents of Japan's VIIT. Section 6 concludes the paper.

2. Theoretical Analysis of the Relationship between Unit Values and Factor Intensities

In this section, we present a simple theoretical model to examine the relationship between unit values and factor intensities. We begin by providing a model in which factories, in order to produce commodities of a high quality, engage in production processes that are intensive in both skilled labor and capital. Next, using this framework, we derive an econometric model to estimate the relationship between output unit values and factor contents.

We assume the existence of four factors, skilled (white-collar) labor (L_S), unskilled (blue-collar) labor (L_U), capital (K) and intermediate input (M).[2] We focus on a certain manufacturing industry, such as the electrical and precision machinery or the general machinery industry. Suppose that N commodities are produced in this industry. For each commodity, there is a continuum of different qualities [$\underline{q}$, $\overline{q}$]. We assume that each "commodity" in our model corresponds to one product item in the most detailed commodity classification of production and trade statistics and that products that differ only in quality are not recorded as different products in the statistics.

Each commodity is produced by a Leontief-type constant-returns-to-scale production function. We examine the profit maximization behavior of factory i in year t, which produces commodity (n, q), that is, commodity n of quality q. The production function of this factory is defined by

[2] In the *Census of Manufactures*, data on the number of skilled and unskilled workers are not available. What are available, however, are data on the number of non-production and production workers. Since non-production workers tend to be more highly educated and in charge of relatively sophisticated tasks, such as management, monitoring of production processes, planning, and research and development (R&D), we use the ratio of non-production to production workers as a proxy for ratio of skilled to unskilled workers and refer to this variable as the white-collar/blue-collar labor ratio.

$$Y_{q,i,t} = \frac{a_{i,t} c_{n,t}}{e(q_{i,t})} \min\left[\frac{L_{U,q,i,t}}{\alpha}, \frac{L_{S,q,i,t}}{\beta f(q_{i,t})}, \frac{K_{q,i,t}}{\gamma g(q_{i,t})}, \frac{M_{q,i,t}}{\delta h(q_{i,t})}\right] \tag{3.1}$$

where $L_{U,q,i,t}$, $L_{S,q,i,t}$, $K_{q,i,t}$ and $M_{q,i,t}$ denote blue-collar labor, white-collar labor, capital, and intermediate input. $Y_{q,i,t}$ denotes the gross output of factory *i*. $a_{i,t}$ denotes factory *i*'s total factor productivity (TFP) level in comparison with the industry average TFP level in year *t*. To simplify our notation, we omit suffix *n* for variables except for the commodity-specific term $c_{n,t}$. We normalize values $a_{i,t}$ and $c_{n,t}$ so that the average value of $\ln(a_{i,t})$ across all factories producing commodity *n* is zero for any *t*. The parameters α, β, γ and δ are constant positive values satisfying $\alpha + \beta + \gamma + \delta = 1$, and do not depend on *n*.

In order to raise output quality, factories need to change their amount of factor inputs. The relationship between output quality and factor inputs is determined by four functions, $e(q_{i,t})$, $f(q_{i,t})$, $g(q_{i,t})$, and $h(q_{i,t})$. These functions are continuously differentiable in *q*, take positive values for any $q \in [\underline{q}, \overline{q}]$, $0 < \underline{q} < 1 < \overline{q}$, and satisfy $e(1)=1$, $f(1)=1$, $g(1)=1$ and $h(1)=1$. What is of key interest in our analysis are the signs of $f'(q_{i,t})$ and $g'(q_{i,t})$. If these derivatives are positive, we will have the relationship that as $q_{i,t}$ approaches $\overline{q}$, the commodity becomes more white-collar labor and physical-capital intensive. To simplify our analysis, we also assume that the elasticities of these functions in $q_{i,t}$ are constant. We express these elasticity values by $\eta_Y=(q_{i,t}\, de(q_{i,t}))/(e(q_{i,t})\, dq_{i,t})$, $\eta_S=(q_{i,t}\, df(q_{i,t}))/(f(q_{i,t})\, dq_{i,t})$, $\eta_K=(q_{i,t}\, dg(q_{i,t}))/(g(q_{i,t})\, dq_{i,t})$, $\eta_M=(q_{i,t}\, dh(q_{i,t}))/(h(q_{i,t})\, dq_{i,t})$, respectively.

We assume that all factories are price takers in factor markets. Let $w_{U,t}$, $w_{S,t}$, r_t and $p_{M,t}$ denote the wage rate for blue-collar workers, the wage rate for white-collar workers, the cost of capital, and the price of intermediate input in year *t*. From cost minimization conditions, we have the following relationships:

$$\frac{L_{S,q,i,t}}{L_{U,q,i,t}} = \frac{\beta}{\alpha} f(q_{i,t}) \tag{3.3}$$

$$\frac{K_{q,i,t}}{L_{U,q,i,t}} = \frac{\gamma}{\alpha} g(q_{i,t}) \tag{3.4}$$

$$\frac{M_{q,i,t}}{L_{U,q,i,t}} = \frac{\delta}{\alpha} h(q_{i,t}) \tag{3.5}$$

From the above relationships and our production function, we have the following factor demand functions:

$$\frac{L_{U,q,i,t}}{Y_{q,i,t}} = \frac{\alpha}{a_{i,t} c_{n,t}} e(q_{i,t}) \tag{3.6}$$

$$\frac{L_{S,q,i,t}}{Y_{q,i,t}} = \frac{\beta}{a_{i,t}c_{n,t}} e(q_{i.t}) f(q_{i,t}) \tag{3.7}$$

$$\frac{K_{q,i,t}}{Y_{q,i,t}} = \frac{\gamma}{a_{i,t}c_{n,t}} e(q_{i,t}) g(q_{i,t}) \tag{3.8}$$

$$\frac{M_{q,i,t}}{Y_{q,i,t}} = \frac{\delta}{a_{i,t}c_{n,t}} e(q_{i,t}) h(q_{i,t}) \tag{3.9}$$

We assume monopolistic competition. The price elasticity of demand for each factory's output in this industry is constant and takes the same value for all factories producing commodity *n*. This means that the mark-up ratio will be the same for all factories and we will have the following relationship between factory *i*'s unit production cost, $u_{q,\,i,\,t}$, and the unit value of its output, $p_{q,\,i,\,t}$:

$$p_{q,i,t} = (1+\lambda_n) u_{q.i,t} \tag{3.10}$$

Unit production cost is determined by

$$\begin{aligned} u_{q,i,t} &= w_{U,t}\frac{L_{U,q,i,t}}{Y_{q,i,t}} + w_{S,t}\frac{L_{S,q,i,t}}{Y_{q,i,t}} + r_t\frac{K_{q,i,t}}{Y_{q,i,t}} + p_{M,t}\frac{M_{q,i,t}}{Y_{q,i,t}} \\ &= \frac{e(q_{i,t})}{a_{i,t}c_{n,t}}\left(\alpha w_{U,t} + \beta f(q_{i,t}) w_{S,t} + \gamma g(q_{i,t}) r_t + \delta h(q_{i,t}) p_{M,t}\right) \end{aligned} \tag{3.11}$$

We assume that most of the four elasticity parameters, η_Y, η_S, η_K, η_M, do not take large negative values, so that $u_{q,i}$ is an increasing function of q.

If we take the logarithm of both sides of the above equation and use equation (3.10), we obtain

$$\begin{aligned} \ln(p_{q,i,t}) &= \ln(e(q_{i,t})) + \ln(\alpha w_{U,t} + \beta f(q_{i,t}) w_{S,t} + \gamma g(q_{i,t}) r_t + \delta h(q_{i,t}) p_{M,t}) \\ &\quad - \ln(a_{i,t}) - \ln(c_{n,t}) + \ln(1+\lambda) \end{aligned} \tag{3.12}$$

We make a linear approximation of each term on the right-hand side of the above equation around a certain value of q_t, which we denote by q_t *. If we subtract the average values of each term of equation (3.12) across all factories from both sides of equation (3.12), we obtain

$$\ln\left(p_{q,i}\right)-\overline{\ln\left(p_t\right)}=$$
$$\left(\eta_Y+\frac{\beta f(q_t^*)w_{S,t}\eta_S+\gamma g(q_t^*)r_t\eta_K+\delta h(q_t^*)p_{M,t}\eta_M}{\alpha w_{U,t}+\beta f(q_t^*)w_{S,t}+\gamma g(q_t^*)r_t+\delta h(q_t^*)p_{M,t}}\right)\left(\ln\left(q_{i,t}\right)-\overline{\ln\left(q_t\right)}\right) \quad (3.13)$$
$$-\ln\left(a_{i,t}\right)$$

Variables with upper bars denote average values. To derive the above equation, we used the fact that the average value of $\ln(a_{i,t})$ is equal to zero as a result of our normalization of $a_{i,t}$ and $c_{n,t}$.

By making a linear approximation of equation (3.3) and subtracting average values across all factories from both sides of the equation, we have

$$\ln\left(\frac{L_{S,q,i,t}}{L_{U,q,i,t}}\right)-\overline{\ln\left(\frac{L_{S,t}}{L_{U,t}}\right)}=\eta_S\left(\ln\left(q_{i,t}\right)-\overline{\ln\left(q_t\right)}\right) \quad (3.14)$$

From equations (3.13) and (3.14), we obtain the relationship between the unit value of a product and its white-collar labor intensity:

$$\ln\left(\frac{L_{S,q,i,t}}{L_{U,q,i,t}}\right)-\overline{\ln\left(\frac{L_{S,t}}{L_{U,t}}\right)}=\theta_S\left(\ln\left(p_{q,i,t}\right)-\overline{\ln\left(p_t\right)}\right)+\theta_S\ln\left(a_{i,t}\right) \quad (3.15)$$

By using equation (3.13) and one of the equations (3.4), (3.5) or (3.6), we also obtain the following equations:

$$\ln\left(\frac{K_{q,i,t}}{L_{U,q,i,t}}\right)-\overline{\ln\left(\frac{K_t}{L_{U,t}}\right)}=\theta_K\left(\ln\left(p_{q,i,t}\right)-\overline{\ln\left(p_t\right)}\right)+\theta_K\ln\left(a_{i,t}\right) \quad (3.16)$$

$$\ln\left(\frac{M_{q,i,t}}{L_{U,q,i,t}}\right)-\overline{\ln\left(\frac{M_t}{L_{U,t}}\right)}=\theta_M\left(\ln\left(p_{q,i,t}\right)-\overline{\ln\left(p_t\right)}\right)+\theta_M\ln\left(a_{i,t}\right) \quad (3.17)$$

$$\ln\left(\frac{L_{U,q,i,t}}{Y_{q,i,t}}\right)-\overline{\ln\left(\frac{L_{U,t}}{Y_t}\right)}=\theta_Y\left(\ln\left(p_{q,i,t}\right)-\overline{\ln\left(p_t\right)}\right)+\theta_Y\ln\left(a_{i,t}\right)-\ln\left(a_{i,t}\right) \quad (3.18)$$

where

$$\theta_S = \frac{\eta_S}{\left(\eta_Y + \frac{\beta f(q_t*)w_{S,t}\eta_S + \gamma g(q_t*)r_t\eta_K + \delta h(q_t*)p_{M,t}\eta_M}{\alpha w_{U,t} + \beta f(q_t*)w_{S,t} + \gamma g(q_t*)r_t + \delta h(q_t*)p_{M,t}}\right)}$$

$$\theta_K = \frac{\eta_K}{\left(\eta_Y + \frac{\beta f(q_t*)w_{S,t}\eta_S + \gamma g(q_t*)r_t\eta_K + \delta h(q_t*)p_{M,t}\eta_M}{\alpha w_{U,t} + \beta f(q_t*)w_{S,t} + \gamma g(q_t*)r_t + \delta h(q_t*)p_{M,t}}\right)}$$

$$\theta_M = \frac{\eta_M}{\left(\eta_Y + \frac{\beta f(q_t*)w_{S,t}\eta_S + \gamma g(q_t*)r_t\eta_K + \delta h(q_t*)p_{M,t}\eta_M}{\alpha w_{U,t} + \beta f(q_t*)w_{S,t} + \gamma g(q_t*)r_t + \delta h(q_t*)p_{M,t}}\right)}$$

$$\theta_Y = \frac{\eta_Y}{\left(\eta_Y + \frac{\beta f(q_t*)w_{S,t}\eta_S + \gamma g(q_t*)r_t\eta_K + \delta h(q_t*)p_{M,t}\eta_M}{\alpha w_{U,t} + \beta f(q_t*)w_{S,t} + \gamma g(q_t*)r_t + \delta h(q_t*)p_{M,t}}\right)}$$

These are the four equations that we estimate in order to examine the relationship between output unit values and factor contents. Since we assume constant returns to scale and a constant mark-up ratio, we have the following identity among the coefficients of (3.15)-(3.18):

$$\begin{aligned}
&\theta_Y + \frac{\beta f(q_t*)w_{S,t}}{\alpha w_{U,t} + \beta f(q_t*)w_{S,t} + \gamma g(q_t*)r_t + \delta h(q_t*)p_{M,t}}\theta_S \\
&+ \frac{\gamma g(q_t*)r_t}{\alpha w_{U,t} + \beta f(q_t*)w_{S,t} + \gamma g(q_t*)r_t + \delta h(q_t*)p_{M,t}}\theta_K \\
&+ \frac{\delta h(q_t*)p_{M,t}}{\alpha w_{U,t} + \beta f(q_t*)w_{S,t} + \gamma g(q_t*)r_t + \delta h(q_t*)p_{M,t}}\theta_M = 1
\end{aligned} \tag{3.19}$$

This constraint means that a one percent increase in the unit price of output corresponds to a one percent increase in the unit production cost.

We estimate equations (3.15)-(3.18) under the constraint (3.19). For the constraint (3.19), we use the sample average cost share of white-collar workers as the value of $\beta f(q_t*)w_{S,t}/\{\alpha w_{U,t}+\beta f(q_t*)w_{S,t}+\gamma g(q_t*)r_t+\delta h(q_t*)p_{M,t}\}$. We also use the sample average cost share of capital service input as the value of $\gamma g(q_t*)r_t/\{\alpha w_{U,t}+\beta f(q_t*)w_{S,t}+\gamma g(q_t*)r_t+\delta h(q_t*)p_{M,t}\}$ and the sample average cost share of intermediate input as the value of $\delta h(q_t*)p_{M,t}/\{\alpha w_{U,t}+\beta f(q_t*)w_{S,t}+\gamma g(q_t*)r_t+\delta h(q_t*)p_{M,t}\}$.

3. Data

The core empirical part of this paper estimates the relationship between output unit values and factor intensities, and calculates the factor contents embodied in Japan's VIIT using this relationship. We first describe the data sources for our variables and then explain how our dataset was constructed.

As a first step, using micro-data of the *Census of Manufactures* for Japan and comparing the factor inputs of factories producing the same good, we estimate the relationship between the unit value of gross output and factor intensities based on commodity- and factory-level data. The CM is an annual survey conducted by the Ministry of Economy, Trade and Industry. We use the establishment-level data of the *Larger Establishment Sample* of the CM that covers all manufacturing establishments with 30 or more employees.[3] The CM includes information on shipments by commodity for each establishment as well as other establishment-level data such as the book value of capital, intermediate input, the number of production and non-production workers, the wage bill, and so on. Using the micro-data of the CM, we calculate factor intensities at the establishment level such as the white-collar/blue-collar labor ratio, the capital/blue-collar labor ratio, the intermediate input/blue-collar labor ratio, and the blue-collar labor/output ratio.[4] Moreover, using the information on a 6-digit commodity classification basis, we select only single-product establishments, which we define as establishments where one commodity accounts for more than 60 percent of total shipments. In the CM, there are approximately 2,000 commodities, out of which quantity information is available for approximately 800 commodities. Based on the 60 percent threshold, we calculate the unit value of a commodity (commodity-level shipments divided by quantity) and various factor intensities at the establishment level. As a result, we obtain information both on unit values and factor intensities for approximately 500+ commodities for each year. However, data on the number of production and non-production workers are available only for 1981, 1984, 1987, and 1990, and we cannot distinguish between production and non-production workers after 1990. Therefore, in this paper, we mainly use the micro-data of the CM for these four years to estimate the relationship between the unit value of output and factor intensities. By estimating equations (3.15)-(3.18), we can derive the relationship between the unit value of output and factor intensities. For the estimation, we employ seemingly unrelated regression (SUR) estimations subject to the constraint expressed by equation (3.19). The estimation results will be presented in Section 4.

Moreover, having estimated the relationship between output unit values and factor intensity, we calculate the factor contents of Japan's VIIT using Japan's Trade Statistics. Ideally, to do so we should

[3] The CM consists of two samples, the *Larger Establishment Sample* and the *Smaller Establishment Sample*, which includes data on factories with less than 30 employees. Because data on the number of white-collar and blue-collar workers are not available in the *Smaller Establishment Sample*, we use the data of the *Larger Establishment Sample* for the analysis in this paper. Moreover, in the *Smaller Establishment Sample*, tangible assets data are missing for many establishments.

[4] It could be argued that the distinction between production- and non-production workers does not adequately capture workers' skill level. For example, some production workers with years of work experience may be much more skilled than non-production workers with less work experience. Moreover, educational attainment may be an important determinant of workers' skill and/or a more useful measure of their skill level. However, data on workers' length of service or educational attainment are not available in the CM and the numbers of production and non-production workers are the only data available for our purposes. Also, more disaggregated job categories are not available in the CM. However, according to the *Basic Survey on Wage Structure* for Japan, production workers are clearly less educated than non-production workers. Looking, for example, at data for 1990 for the manufacturing sector shows that 96 percent of production workers had received only primary and secondary education while 42 percent of non-production workers had received tertiary education. Moreover, the average hourly wage for male non-production workers with secondary education was 36 percent higher than that for male production workers with secondary education. Comparing hourly wages for male workers with approximately 14 years of experience in the company, non-production workers on average received a 23 percent higher hourly wage than production workers. Therefore, we believe that the distinction between production and non-production workers can be used as a proxy for skill levels in the empirical analysis in this paper.

match the trade statistics with the commodity-level unit values and factor intensities calculated from the CM,[5] and we tried to match the 9-digit commodity-level trade statistics with the 6-digit commodity level data of the CM. However, we were able to do so only for commodities for which the quantity units were the same in both the CM and the Trade Statistics.[6] For the year 1990, we obtain unit value and factor intensity data for 635 commodities from the CM, out of which export unit value information is available for 354 commodities and import unit value information for 336 commodities. Thus, approximately half of the CM commodities with unit value information cannot be matched to the trade data due to differences in the quantity units. Given these data constraints, we estimate the factor contents of trade at an aggregated industry level, utilizing the unit value information on commodities for which the CM and the Trade Statistics can be matched. More details on our strategy for the estimation of the factor contents of Japan's VIIT are provided in Section 5.

4. Empirical Results on the Relationship between Output Unit Values and Factor Intensities

In this section, we report our estimation results on the relationship between output unit values and factor intensities. We estimate the system of equations (3.15)-(3.18) under the constraint expressed by equation (3.19), using SUR techniques. In the estimation, average values in equations (3.15) – (3.18), i.e., variables with upper bars, are the weighted average of factor intensities or unit values of a product in logarithm. To calculate average values, we used the value of shipments of the product at each establishment as weight. Therefore, for our baseline estimation, the dependent variable is the deviation of the factor intensity at a particular single-product establishment from the weighted average of the factor intensity at all single-product establishments producing that product.[7] The explanatory variable is the deviation of the unit value of a product at a particular single-product establishment from the weighted average of the unit values at all single-product establishments producing the product. Although equations (3.15)-(3.18) include a productivity term on the right-hand side, in our baseline estimation we treat this as being included in the error term. The reason is that it is extremely difficult to calculate quality-adjusted productivity, which our theoretical model assumes. However, as a robustness check, we also estimate the equations controlling for the TFP level of each establishment estimated without considering quality differences. In order to take account of the possibility that factor intensities and production technologies may differ across industries, we estimated the system of equations separately for the following ten manufacturing subsectors: food, textiles, wood, chemicals, ceramics, metals, general machinery, electrical and precision machinery,

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[5] In the case of Japan's trade statistics, classification at the 9-digit commodity level is available, which is much more detailed than the commodity classification for the CM. For example, for 1990, we identified 6,716 export commodities and 8,744 import commodities at the 9-digit commodity level in the Trade Statistics compared with only 1,853 commodities at the 6-digit level in the CM.

[6] There are various quantity units reported in the CM and the Trade Statistics. In the case of the Trade Statistics, approximately 90 percent of commodities with quantity information are reported in terms of kilograms or tons. However, in the case of the CM, the unit "number" is the most frequent quantity unit, although there are also many commodities that are reported in terms of tons.

[7] In our estimation, we use real values for capital stock and real intermediate input, which are constructed using the JIP2006 industry-level deflators (with 1995 as the base year). As for output, we use the output quantity.

transportation equipment, and miscellaneous products.[8] A full set of year dummies is included in order to capture industry-level productivity shocks over time.

The estimation results are reported in Table 1. The most important result is that in the case of the relationship between unit values and the white-collar/blue-collar labor ratio, the coefficient is positive for all subsectors except transportation equipment, and statistically significant for eight subsectors. That is, to produce high unit-value products, factories need a high white-collar/blue-collar labor ratio. White-collar labor tends to be more abundant and therefore relatively cheap in developed economies, so that developed economies are expected to have a comparative advantage in white-collar labor intensive products. Our finding that more expensive products are more white-collar labor intensive is consistent with the well known stylized fact that developed economies tend to export products with higher unit values and import products with lower unit values (Fukao et al., 2003; Schott 2004).

Table 1. Relationship between factor intensity and unit price: Seemingly Unrelated Regression estimations with constraint

		Food	Textiles	Wood	Chemicals	Ceramics	Metals	General machinery	Electrical and precision machinery	Transpor-tation equipment	Miscellane-ous products
Equation number	Dependent variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(3.15)	dvlnWBratio	0.088**	0.119***	0.050	0.165***	0.097***	0.056***	0.115***	0.117***	-0.002	0.315***
		(0.040)	(0.017)	(0.033)	(0.022)	(0.027)	(0.015)	(0.014)	(0.020)	(0.023)	(0.058)
(3.16)	dvlnKBratio	-0.248***	0.073***	-0.051	0.132***	0.004	-0.110***	0.048***	0.155***	0.051	0.140**
		(0.044)	(0.018)	(0.048)	(0.029)	(0.031)	(0.020)	(0.015)	(0.025)	(0.034)	(0.068)
(3.17)	dvlnMBratio	-0.282***	0.131***	-0.026	-0.037*	-0.047**	-0.179***	0.079***	0.051***	0.025	0.067
		(0.035)	(0.018)	(0.033)	(0.020)	(0.021)	(0.015)	(0.013)	(0.017)	(0.026)	(0.044)
(3.18)	dvlnBYratio	1.217***	0.897***	1.021***	1.007***	1.022***	1.134***	0.931***	0.946***	0.979***	0.928***
		(0.029)	(0.014)	(0.028)	(0.016)	(0.016)	(0.012)	(0.010)	(0.015)	(0.021)	(0.034)
	Number of observations	3006	6712	1942	4331	5515	8270	2267	1736	906	1074

Notes: 1. The dependent variables are factor intensities expressed in logarithmic form (deviation from the commodity-year mean).
2. Standard errors are in parentheses, with ***, ** and * indicating significance at the 1, 5 and 10 percent level, respectively.
3. Constant terms and year dummies are included, but estimated coefficients are not reported.
4. For the estimation, pooled data of factories with 30 or more employees in 1981, 1984, 1987, 1990 were used.

The relationship between the capital/blue-collar labor ratio and unit values and that between the intermediate input/blue-collar labor ratio and unit values differ across subsectors. For example, the unit value coefficient in the capital/blue-collar labor ratio equation is positive and significant in five subsectors (textiles, chemicals, general machinery, electrical and precision machinery, and miscellaneous products) but negative and significant in two subsectors (food and metals).

It is interesting to note that the coefficient in the blue-collar labor/gross output ratio equation is greater than 0.9 in all subsectors. This result implies that in order to raise the unit value of their output by 10 percent, factories need to increase their blue-collar labor input per output by more than 9 percent. In other words, in order to produce higher unit value products, an increase only of white-collar labor input or

[8] For the classification of industries, see Appendix Table 1.

of capital is not sufficient. Our estimation results show that even if factories increase their white-collar/blue-collar labor ratio, they also need to increase the input/output ratio for all other inputs simultaneously.[9]

In order to check the robustness of our results, we also estimate the system of four equations (3.15)-(3.19) controlling for the TFP level of each establishment. Following Good, Nadiri, and Sickles (1997), the TFP index is calculated as the deviation of an establishment's TFP level from the TFP level of a hypothetical representative establishment in the relevant industry in the base year (1981 in this paper).[10] Moreover, as another robustness check of our results, we estimate the system of four equations without the constraint (3.19). The results controlling for establishments' TFP level and those estimated without the constraint are reported in Tables 2 and 3, respectively. The results are consistent with those in Table 1 in most of the subsectors.[11]

Table 2. Relationship between factor intensity and unit price: Seemingly Unrelated Regression estimations with constraint, TFP controlled

		Food	Textiles	Wood	Chemicals	Ceramics	Metals	General machinery	Electrical and precision machinery	Transpor-tation equipment	Miscellane-ous products
Equation number	Dependent variable / Explanatory variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(3.15)	dvlnWBratio										
	dvlnUV	0.097**	0.087***	0.049	0.154***	0.092***	0.051***	0.116***	0.093***	-0.005	0.302***
		(0.041)	(0.017)	(0.033)	(0.022)	(0.027)	(0.015)	(0.014)	(0.020)	(0.023)	(0.058)
	lnTFP	0.111**	0.909***	0.137*	0.109**	0.062	0.319***	0.210***	0.975***	0.345***	0.411***
		(0.052)	(0.049)	(0.081)	(0.050)	(0.041)	(0.038)	(0.074)	(0.090)	(0.097)	(0.121)
(3.16)	dvlnKBratio										
	dvlnUV	-0.268***	0.062***	-0.045	0.120***	0.017	-0.101***	0.056***	0.131***	0.057*	0.150**
		(0.044)	(0.018)	(0.049)	(0.029)	(0.032)	(0.020)	(0.016)	(0.025)	(0.034)	(0.070)
	lnTFP	0.207***	0.296***	-0.335***	-0.119*	-0.163***	0.151***	-0.181**	1.248***	-0.049	-0.120
		(0.057)	(0.053)	(0.120)	(0.065)	(0.048)	(0.049)	(0.081)	(0.112)	(0.142)	(0.145)
(3.17)	dvlnMBratio										
	dvlnUV	-0.298***	0.082***	-0.025	-0.073***	-0.045**	-0.189***	0.077***	0.022	0.023	0.040
		(0.035)	(0.017)	(0.032)	(0.019)	(0.022)	(0.015)	(0.013)	(0.016)	(0.026)	(0.044)
	lnTFP	0.545***	0.991***	0.409***	0.297***	0.404***	0.349***	0.118*	0.864***	0.220**	0.195**
		(0.045)	(0.050)	(0.080)	(0.043)	(0.033)	(0.038)	(0.066)	(0.074)	(0.108)	(0.093)
(3.18)	dvlnBYratio										
	dvlnUV	1.229***	0.934***	1.019***	1.035***	1.020***	1.141***	0.932***	0.971***	0.980***	0.949***
		(0.029)	(0.013)	(0.027)	(0.016)	(0.016)	(0.012)	(0.010)	(0.014)	(0.021)	(0.035)
	lnTFP	-0.983***	-1.438***	-1.177***	-0.937***	-1.092***	-1.093***	-0.857***	-1.504***	-0.928***	-0.895***
		(0.041)	(0.038)	(0.070)	(0.038)	(0.028)	(0.032)	(0.055)	(0.063)	(0.090)	(0.074)
Number of observations		2940	6665	1931	4292	5461	8223	2248	1716	893	1066

Notes: 1. The dependent variables are factor intensities expressed in logarithmic form (deviation from the commodity-year mean).
2. Standard errors are in parentheses, with ***, ** and * indicating significance at the 1, 5 and 10 percent level, respectively.
3. Constant terms and year and industry dummies are included, but estimated coefficients are not reported.
4. For the estimation, pooled data of factories with 30 or more employees in 1981, 1984, 1987, 1990 were used.

9 From equations (3.17) and (3.18), we have the following relationship:

$$\ln\left(\frac{K_{U,q,i,t}}{Y_{q,i,t}}\right)-\overline{\ln\left(\frac{K_{U,t}}{Y_t}\right)}=(\theta_K+\theta_Y)\theta_Y\left(\ln(p_{q,i,t})-\overline{\ln(p_t)}\right)+\theta_K\ln(a_{i,t})+\theta_Y\ln(a_{i,t})-\ln(a_{i,t})$$

Taking the electrical machinery industry as an example, this implies that in order to raise the unit value of output by 10 percent, factories need to increase their capital input per output by 1.55+9.46=11.01 percent (see column (8) in Table 1).

10 This TFP index does not take account of quality differences in output, labor, and other input factors.

11 We should note that high output prices may reflect high mark-ups rather than high product quality. In order to examine this issue, we estimated equations (3.15)-(3.18) jointly, using unit production costs in place of unit output prices. We obtained results that are very similar to those in Tables 1 and 2 (see Appendix Table 2). Therefore, we conclude that high output prices reflect high product quality.

Table 3. Relationship between factor intensity and unit price: Seemingly Unrelated Regression estimations without constraint

Equation number	Dependent variable	Food (1)	Textiles (2)	Wood (3)	Chemicals (4)	Ceramics (5)	Metals (6)	General machinery (7)	Electrical and precision machinery (8)	Transpor-tation equipment (9)	Miscellane-ous products (10)
(3.15)	dvlnWBratio	0.032	0.125***	0.050	0.168***	0.104***	0.057***	0.114***	0.120***	-0.002	0.340***
		(0.040)	(0.017)	(0.033)	(0.022)	(0.027)	(0.015)	(0.014)	(0.020)	(0.023)	(0.058)
(3.16)	dvlnKBratio	-0.185***	0.073***	-0.056	0.131***	-0.013	-0.107***	0.047***	0.166***	0.051	0.152**
		(0.044)	(0.018)	(0.049)	(0.029)	(0.031)	(0.020)	(0.015)	(0.026)	(0.034)	(0.068)
(3.17)	dvlnMBratio	-0.169***	0.127***	-0.025	-0.047**	-0.006	-0.178***	0.079***	0.047***	0.024	0.052
		(0.036)	(0.018)	(0.033)	(0.020)	(0.022)	(0.015)	(0.013)	(0.017)	(0.026)	(0.044)
(3.18)	dvlnBYratio	0.933***	0.879***	1.001***	0.933***	0.890***	1.115***	0.920***	0.924***	0.976***	0.844***
		(0.035)	(0.014)	(0.031)	(0.018)	(0.021)	(0.014)	(0.011)	(0.016)	(0.023)	(0.038)
	Number of observations	3006	6712	1942	4331	5515	8270	2267	1736	906	1074

Notes: 1. The dependent variables are factor intensities expressed in logarithmic form (deviation from the commodity-year mean).
2. Standard errors are in parentheses, with ***, ** and * indicating significance at the 1, 5 and 10 percent level, respectively.
3. Constant terms and year dummies are included, but estimated coefficients are not reported.
4. For the estimation, pooled data of factories with 30 or more employees in 1981, 1984, 1987, 1990 were used.

One caveat regarding the CM data is that they do not cover the activities of headquarters if these are not located in the same place as the factory. This means that headquarter activities, such as research and development, design, and advertising, which tend to be white-collar labor and capital-intensive and are necessary to produce and sell high-quality products, are included for some observations but not for others. This means that the coefficients in the regressions for the white-collar/blue-collar labor ratio and the capital/blue-collar labor ratio may be biased. Another potential problem of our estimation is that the unit value of output could be arbitrary and not convey meaningful information if the output is traded within the firm. In order to examine whether our estimates are affected by these potential issues, we re-estimate the system of four equations (without the constraint) using only data of factories belonging to firms with no additional factory and whose headquarters are located in the same place. As Table 4 shows, the results are largely similar to those in Tables 1, 2, and 3.[12]

[12] We also estimated the system of four equations without the constraint (3.19) controlling for TFP and using only data of factories belonging to firms with no additional factory and whose headquarters are located in the same place. The results are consistent with those in Tables 1 to 4. The results can be obtained from the authors upon request.

Table 4. Relationship between factor intensity and unit price: Seemingly Unrelated Regression estimations without constraint, based on data of factories belonging to firms with no additional factory and whose headquarters are located in the same place

Equation number	Dependent variable	Food (1)	Textiles (2)	Wood (3)	Chemicals (4)	Ceramics (5)	Metals (6)	General machinery (7)	Electrical and precision machinery (8)	Transpor-tation equipment (9)	Miscellane-ous products (10)
(3.15)	dvlnWBratio	0.122**	0.123***	-0.001	0.224***	0.157***	0.064***	0.117***	0.132***	-0.010	0.209***
		(0.058)	(0.022)	(0.042)	(0.038)	(0.044)	(0.022)	(0.020)	(0.036)	(0.030)	(0.075)
(3.16)	dvlnKBratio	-0.199***	0.078***	-0.039	0.049	-0.140**	-0.076***	0.051**	0.079*	-0.021	0.219**
		(0.067)	(0.024)	(0.058)	(0.051)	(0.056)	(0.029)	(0.023)	(0.043)	(0.051)	(0.096)
(3.17)	dvlnMBratio	-0.186***	0.091***	-0.063	-0.053	-0.001	-0.167***	0.106***	0.011	-0.044	0.020
		(0.052)	(0.023)	(0.046)	(0.036)	(0.037)	(0.023)	(0.019)	(0.030)	(0.034)	(0.053)
(3.18)	dvlnBYratio	1.055***	0.903***	1.051***	0.964***	0.880***	1.127***	0.893***	0.962***	1.031***	0.875***
		(0.050)	(0.019)	(0.042)	(0.028)	(0.035)	(0.020)	(0.016)	(0.027)	(0.030)	(0.046)
	Number of observations	1578	3547	963	1448	2245	3766	1050	601	468	561

Notes: 1. The dependent variables are factor intensities expressed in logarithmic form (deviation from the commodity-year mean).
2. Standard errors are in parentheses, with ***, ** and * indicating significance at the 1, 5 and 10 percent level, respectively.
3. Constant terms and year dummies are included, but estimated coefficients are not reported.
4. For the estimation, pooled data of factories with 30 or more employees in 1981, 1984, 1987, 1990 were used.

However, our estimation results may still be biased because single-product establishments are likely to be smaller than multi-product establishments producing products that fall into different commodity categories, and because factor intensities for smaller establishments may be different from those for larger establishments. Therefore, as an additional robustness check, we estimate the system of four equations using all the available observations, that is, not only observations for single-product establishments but also for multi-product establishments. To do so, we rewrite equations (3.15)-(3.18) using the weighted averages of factor intensities and of unit values. For example, equation (3.15) can be rewritten as:

$$\ln\left(\frac{L^i_{S,q,t}}{L^i_{U,q,t}}\right) - \sum_n \omega^i_n \overline{\ln\left(\frac{L_{S,n,t}}{L_{U,n,t}}\right)} = \theta_S \sum_n \omega^i_n \left(\ln\left(p^i_{q,n,t}\right) - \overline{\ln\left(p_{n,t}\right)}\right) + \theta_S \ln\left(a_{i,t}\right) \quad (3.15)'$$

where ω_n^i denotes the share of commodity *n* in factory *i*'s total shipments. The first term on the left-hand side denotes the white-collar/blue-collar labor ratio for factory *i* in logarithm. The variable with an upper bar in the second term on the left-hand side denotes the weighted average of the white-collar/blue-collar labor ratios (in logarithm) for all single-product factories producing commodity *n*, using the value of shipments of commodity *n* for each factory as weight. The term in the bracket of the first term on the right-hand side is the unit value of commodity *n* for factory *i* (in logarithm) minus the weighted average of the unit value (in logarithm) of commodity *n* for all single-product factories producing commodity *n*, using the value of shipments of commodity *n* for each factory as weight. Similarly, we can rewrite equations (3.16)-(3.18) and estimate the system of four equations. The estimation results are shown in Appendix Tables 3, 4, and 5, which are largely consistent with those in Tables 1 to 4.

5. Factor Contents in Japan's VIIT

In this section we estimate the factor contents of Japan's VIIT. We first present our theoretical framework and then, using concrete examples, show how we obtain the necessary data for the factor content analysis. Finally, we calculate the factor contents.

We can derive factor contents of international trade from our estimators of elasticity values as well as the factor demand functions. We assume that $a_{i,t}$ is close to one for any i and any t. Using equations (3.15) and (3.18), we can express the ratio of the white-collar labor input to the output quantity for a factory which produces commodity (n, q) as follows:

$$\frac{L_{S,n,t}(p_t)}{Y_{n,t}(p_t)} = c'_{n,t} p_t^{\theta_S+\theta_Y} \tag{3.20}$$

where $c'_{n,t}$ denotes a commodity- and year-specific constant term.

Let $\varphi_{D,n,t}(p_t)$ denote the distribution function of output quantity by all the factories producing commodity n in Japan over unit value p. Then, we can derive the following equation from (3.20):

$$L_{S,D,n,t} = Y_{D,n,t} c'_{n,t} \int_{p_t=0}^{+\infty} p_t^{\theta_S+\theta_Y} \varphi_{D,n,t}(p_t) dp_t \tag{3.21}$$

where $L_{S,D,n,t}$ denotes the total input of white-collar labor in products made in Japan of n and $Y_{D,n,t}$ denotes the total domestic output quantity of n. Finally, white-collar labor embodied in Japan's exports of commodity n, $L_{S,E,n,t}$, and imports, $L_{S,I,n,t}$, is given by

$$L_{S,E,n,t} = Y_{E,n,t} \frac{L_{S,D,n,t}}{Y_{D,n,t}} \frac{\int_{p_t=0}^{+\infty} p_t^{\theta_S+\theta_Y} \varphi_{E,n,t}(p_t) dp_t}{\int_{p_t=0}^{+\infty} p_t^{\theta_S+\theta_Y} \varphi_{D,n,t}(p_t) dp_t} \tag{3.22}$$

$$L_{S,I,n,t} = Y_{I,n,t} \frac{L_{S,D,n,t}}{Y_{D,n,t}} \frac{\int_{p_t=0}^{+\infty} p_t^{\theta_S+\theta_Y} \varphi_{I,n,t}(p_t) dp_t}{\int_{p_t=0}^{+\infty} p_t^{\theta_S+\theta_Y} \varphi_{D,n,t}(p_t) dp_t} \tag{3.23}$$

where $Y_{E,n,t}$ and $Y_{I,n,t}$ denote the total export volume and total import volume of commodity n. $\varphi_{E,n,t}(p_t)$ and $\varphi_{I,n,t}(p_t)$ denote the distribution functions of export and import quantity over unit value. Usually, we do not know these distribution functions. But we do know the average unit value of exports and imports:

$$p_t^E = \int_{p_t=0}^{+\infty} p_t \varphi_{E,n,t}(p_t) dp_t \tag{3.24}$$

$$p_t^I = \int_{p_t=0}^{+\infty} p_t \varphi_{I,n,t}(p_t) dp_t \tag{3.25}$$

By using equations (3.16)-(3.18), we also obtain the following equations:

$$K_{E,n,t} = Y_{E,n,t} \frac{K_{D,n,t}}{Y_{D,n,t}} \frac{\int_{p_t=0}^{+\infty} p_t^{\theta_K+\theta_Y} \varphi_{E,n,t}(p_t) dp_t}{\int_{p_t=0}^{+\infty} p_t^{\theta_K+\theta_Y} \varphi_{D,n,t}(p_t) dp_t} \tag{3.26}$$

$$K_{I,n,t} = Y_{I,n,t} \frac{K_{D,n,t}}{K_{n,t}} \frac{\int_{p_t=0}^{+\infty} p_t^{\theta_K+\theta_Y} \varphi_{I,n,t}(p_t) dp_t}{\int_{p_t=0}^{+\infty} p_t^{\theta_K+\theta_Y} \varphi_{D,n,t}(p_t) dp_t} \tag{3.27}$$

$$L_{U,E,n,t} = Y_{E,n,t} \frac{L_{U,D,n,t}}{Y_{D,n,t}} \frac{\int_{p_t=0}^{+\infty} p_t^{\theta_Y} \varphi_{E,n,t}(p_t) dp_t}{\int_{p_t=0}^{+\infty} p_t^{\theta_Y} \varphi_{D,n,t}(p_t) dp_t} \tag{3.28}$$

$$L_{U,I,n,t} = Y_{I,n,t} \frac{L_{U,D,n,t}}{Y_{D,n,t}} \frac{\int_{p_t=0}^{+\infty} p_t^{\theta_Y} \varphi_{I,n,t}(p_t) dp_t}{\int_{p_t=0}^{+\infty} p_t^{\theta_Y} \varphi_{D,n,t}(p_t) dp_t} \tag{3.29}$$

Next, using concrete examples, we show how we obtain the necessary data for our factor content analysis, such as the unit value of the shipments of a particular product by firms in Japan, of exports and of imports of that product, and the standard deviation of the unit values of shipments of that product. [13]

Table 5 provides summary information of our unit value analysis for the case of "cotton tubular knit fabric," a category at the most disaggregated, 6-digit commodity category level of the CM. We can calculate unit values and factor contents for 14 factories for 1990. The average unit value of the gross output of these single-product factories is 1.36 million yen per ton. The standard deviation of the natural log of unit values across factories is 0.607. "Cotton tubular knit fabric" covers three commodity categories in the 9-digit commodity classification of the Harmonized System (HS) in the case of Japan's exports and sixcommodity categories in the case of Japan's imports.

[13] In the CM, we cannot distinguish between shipments for the domestic market and shipments for the export market. Moreover, there is no information on exports by each establishment and we cannot distinguish whether an establishment is involved in exporting/importing or not. In 2001, however, a question was added in the CM asking for the export-shipment ratio of each establishment. Thus, for years from 2001 onward, it is possible to distinguish between the unit value of products made in non-exporting establishments and the unit value of products made in exporting establishments.

Table 5. Summary table of the unit value analysis: The case of cotton tubular knit fabric

Unit value data of the *Census of Manufactures 1990*

Commodity classification name in the *Census of Manufactures*	Cotton tubular knit fabric
Commodity code	1451-11
Number of factories whose data were used	14
Number of white-collar workers per one million yen gross output	0.0066
Number of blue-collar workers per one million yen gross output	0.0167
Capital stock (in million yen) per one million yen gross output	0.1257
Average unit value (million yen per ton)	1.3571
Standard deviation of unit value (million yen per ton)	1.6016
Average of natural log of unit value	0.0393
Standard deviation of natural log of unit value	0.6073

Corresponding Trade Statistics for 1990

Exports

HS 9-digit code	HS 9-digit name			
600210190	Knitted or crocheted fabrics of a width not exceeding 30 cm, containing by weight 5% or more of elastomeric yarn or rubber thread, made of cottor			
	Unit value of exports (million yen per ton)	2.240	Quantity of exports (ton)	15.497
	Value of exports (million yen)	34.709		
600220190	Knitted or crocheted fabrics of a width not exceeding 30 cm, made of cotton, other than those of heading 600210			
	Unit value of exports (million yen per ton)	2.583	Quantity of exports (ton)	13.849
	Value of exports (million yen)	35.768		
600230190	Knitted or crocheted fabrics of a width exceeding 30 cm, containing by weight 5% or more of elastomeric yarn or rubber thread, made of cotton			
	Unit value of exports (million yen per ton)	2.527	Quantity of exports (ton)	52.484
	Value of exports (million yen)	132.633		
Total value of exports (million yen)		203.110	Total volume of exports	81.830
Total value of exports/total volume of exports (million yen)		2.482		
Weighted average of unit value of exports (weight: value of exports)		2.488		

Imports

HS 9-digit code	HS 9-digit name			
600210031	Knitted or crocheted fabrics of a width not exceeding 30 cm, containing by weight 5% or more of rubber thread, not figured, made of cotton			
	Unit value of imports (million yen per ton)	1.903	Quantity of imports (ton)	7.579
	Value of imports (million yen)	14.423		
600210092	Knitted or crocheted fabrics of a width not exceeding 30 cm, containing by weight 5% or more of elastomeric yarn, not figured, made of cotton			
	Unit value of imports (million yen per ton)	n.a.	Quantity of imports (ton)	0
	Value of imports (million yen)	0.000		
600220022	Knitted or crocheted fabrics of a width not exceeding 30 cm, not figured, made of cotton, other than those of heading 600210			
	Unit value of imports (million yen per ton)	0.731	Quantity of imports (ton)	32.095
	Value of imports (million yen)	23.469		
600230031	Knitted or crocheted fabrics of a width exceeding 30 cm, containing by weight 5% or more of rubber thread, not figured, made of cotton			
	Unit value of imports (million yen per ton)	5.614	Quantity of imports (ton)	0.057
	Value of imports (million yen)	0.320		
600230092	Knitted or crocheted fabrics of a width exceeding 30 cm, containing by weight 5% or more of elastomeric yarn, not figured, made of cotton			
	Unit value of imports (million yen per ton)	9.790	Quantity of imports (ton)	0.200
	Value of imports (million yen)	1.958		
600292020	Knitted or crocheted fabrics, not figured, made of cotton, other than those of heading 600210, 600220, and 600230			
	Unit value of imports (million yen per ton)	1.382	Quantity of imports (ton)	364.215
	Value of imports (million yen)	503.195		
Total value of imports (million yen)		543.365	Total volume of imports (ton)	404.146
Unit value (Total value of imports/total volume of imports, million yen per t		1.344		
Weighted average of unit value of imports (weight: value of imports)		1.400		

It is interesting to note that the unit value of Japan's exports (2.48 million yen per ton), which is calculated as the total value of exports over the total volume of exports, is more than 50 percent higher than the unit value of total shipments by single-product factories (1.36 million yen per ton). Probably, two factors contribute to this gap in unit values. One is that among factories in Japan, only those factories that are white-collar labor-intensive and producing output with a high unit value may be engaged in exporting. The other factor is that the observations for our unit value analysis consist only of single-product factories, which may be less white-collar labor-intensive and produce cheaper products than the average factory in Japan. On the other hand, the unit value of Japan's imports (1.34 million yen per ton) is almost the same as the unit value of the total shipments by single-product factories.

Next, Table 6 provides summary information of our unit value analysis for the case of "light and small passenger cars," another category at the 6-digit commodity level of the CM. We can calculate unit values and factor contents for 9 factories for 1990. The average unit value of the gross output of these single-product factories is 0.943 million yen per unit, and the standard deviation of the natural log of unit values across factories is 0.237. "Light and small passenger cars" cover seven commodity categories in the 9-digit commodity classification of the Harmonized System (HS) in the case of Japan's exports and five commodity categories in the case of Japan's imports.

Table 6. Summary table of the unit value analysis: The case of light and small passenger cars

Unit value data of the *Census of Manufactures 1990*

Commodity classification name in the *Census of Manufactures*	Light and small passenger cars, less than 2000ml cylinder capacity, including chassis
Commodity code	3111-11
Number of factories whose data were used	9
Number of white-collar workers per one million yen gross output	0.0024
Number of blue-collar workers per one million yen gross output	0.0065
Capital stock (in million yen) per one million yen gross output	0.0824
Average unit value (million yen per unit)	0.9431
Standard deviation of unit value (million yen per unit)	0.2069
Average of natural log of unit value	4.5229
Standard deviation of natural log of unit value	0.2374

Corresponding Trade Statistics for 1990

Exports

HS 9-digit code	HS 9-digit name			
870321910	Passenger automobiles, with spark-ignition internal combustion reciprocating piston engine, of a cylinder capacity not exceeding 550cc, excluding knock down products			
	Unit value of exports (million yen per unit)	0.302	Quantity of exports (unit)	12,730
	Value of exports (million yen)	3,848		
870321920	Passenger automobiles, with spark-ignition internal combustion reciprocating piston engine, of a cylinder capacity exceeding 550cc and not exceeding 1,000cc, excluding knock down products			
	Unit value of exports (million yen per unit)	0.587	Quantity of exports (unit)	215,033
	Value of exports (million yen)	126,218		
870322900	Passenger automobiles, with spark-ignition internal combustion reciprocating piston engine, of a cylinder capacity exceeding 1,000cc and not exceeding 1,500cc, excluding knock down products			
	Unit value of exports (million yen per unit)	0.814	Quantity of exports (unit)	1,027,269
	Value of exports (million yen)	836,088		
870323910	Passenger automobiles, with spark-ignition internal combustion reciprocating piston engine, of a cylinder capacity exceeding 1,500cc and not exceeding 2,000cc, excluding knock down products			
	Unit value of exports (million yen per unit)	1.152	Quantity of exports (unit)	1,589,365
	Value of exports (million yen)	1,831,106		
870331910	Passenger automobiles, with compression-ignition internal combustion reciprocating piston engine, of a cylinder capacity not exceeding 1,000cc, excluding knock down products			
	Unit value of exports (million yen per unit)	0.679	Quantity of exports (unit)	2,688
	Value of exports (million yen)	1,826		
870331920	Passenger automobiles, with compression-ignition internal combustion reciprocating piston engine, of a cylinder capacity exceeding 1,000cc and not exceeding 1,500cc, excluding knock down products			
	Unit value of exports (million yen per unit)	0.769	Quantity of exports (unit)	2,425
	Value of exports (million yen)	1,866		
870332910	Passenger automobiles, with compression-ignition internal combustion reciprocating piston engine, of a cylinder capacity exceeding 1,500cc and not exceeding 2,000cc, excluding knock down products			
	Unit value of exports (million yen per unit)	0.929	Quantity of exports (unit)	79,611
	Value of exports (million yen)	73,921		
Total value of exports (million yen)		2,874,872	Total volume of exports	2,929,121
Total value of exports/total volume of exports (million yen)		0.981		
Weighted average of unit value of exports (weight: value of exports)		1.021		

Imports

HS 9-digit code	HS 9-digit name			
870321000	Passenger automobiles, with spark-ignition internal combustion reciprocating piston engine, of a cylinder capacity not exceeding 1,000cc			
	Unit value of imports (million yen per unit)	0.842	Quantity of imports (unit)	17,974
	Value of imports (million yen)	15,140		
870322000	Passenger automobiles, with spark-ignition internal combustion reciprocating piston engine, of a cylinder capacity exceeding 1,000cc and not exceeding 1,500cc			
	Unit value of imports (million yen per unit)	1.064	Quantity of imports (unit)	9,300
	Value of imports (million yen)	9,895		
870323000	Passenger automobiles, with spark-ignition internal combustion reciprocating piston engine, of a cylinder capacity exceeding 1,500cc and not exceeding 3,000cc			
	Unit value of imports (million yen per unit)	2.951	Quantity of imports (unit)	171,001
	Value of imports (million yen)	504,628		
870331000	Passenger automobiles, with compression-ignition internal combustion reciprocating piston engine, of a cylinder capacity not exceeding 1,500cc			
	Unit value of imports (million yen per unit)	1.772	Quantity of imports (unit)	3
	Value of imports (million yen)	5		
870332000	Passenger automobiles, with compression-ignition internal combustion reciprocating piston engine, of a cylinder capacity exceeding 1,500cc and not exceeding 2,500cc			
	Unit value of imports (million yen per unit)	2.044	Quantity of imports (unit)	2,740
	Value of imports (million yen)	5,600		
Total value of imports (million yen)		535,269	Total volume of imports (unit)	201,018
Unit value (Total value of imports/total volume of imports, million ye		2.663		
Weighted average of unit value of imports (weight: value of imports)		2.847		

In the case of this type of cars, the unit value of Japan's exports (0.981 million yen unit) is almost equal to the unit value of all shipments by single-product factories in Japan (0.943 million yen per unit). On the other hand, the unit value of Japan's imports (2.66 million yen per unit) is much higher than the unit value of all shipments by single-product factories and the unit value of exports. A probable reason is that Japan imports mainly luxury cars.

Using such unit value information taken from the CM and the trade statistics as well as data on factor intensities for each commodity, we can estimate the factor contents of Japan's VIIT based on equations (3.22), (3.23) and (3.26)-(3.29). Ideally, we should calculate the factor contents of trade at the commodity level. However, as we explain below, due to data constraints we estimate the factor contents of trade at a more aggregated level. Moreover, although $Y_{D,n,t}$, $Y_{E,n,t}$ and $Y_{I,n,t}$, are assumed to be the quantity or volume of domestic output, exports, and imports, we use domestic output value and export and import values instead to estimate the factor contents of trade because there is no quantity information for many commodities in the CM and because the quantity units differ between the CM and the Trade Statistics for many commodities.

As already mentioned, we do not know the distribution functions of export and import quantities over unit values, $\varphi_{E,n,t}(p_t)$ and $\varphi_{I,n,t}(p_t)$, but we do know the average unit value of exports and imports. Therefore, we assume that $\varphi_{E,n,t}(p_{n,t})$ and $\varphi_{I,n,t}(p_t)$ follow a log normal distribution and their standard deviations are equal to the standard deviation of the distribution function of output quantity for all factories producing commodity n in Japan over unit value p, $\varphi_{D,n,t}(p_t)$.[14] If we assume that $\varphi_{E,n,t}(p_{n,t})$ and $\varphi_{I,n,t}(p_t)$ follow a log normal distribution, we can simplify equations (3.22), (3.23) and (3.26)-(3.29). For example, equation (3.22) can be rewritten as:

$$L_{S,E,n,t} = Y_{E,n,t}\frac{L_{S,D,n,t}}{Y_{D,n,t}}\exp\left\{(\theta_S+\theta_Y)(\mu_E-\mu_D)+\frac{1}{2}(\theta_S+\theta_Y)^2(\sigma_E^2-\sigma_D^2)\right\} \quad (3.22)'$$

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where μ_E and μ_D denote the log of the unit value of Japan's exports and the a[illegible] of the factory-level unit values in logarithm, respectively, for commodity n. σ_E and σ_D denote the standard deviation of the distribution functions of exports and of all shipments by single-product factories, respectively, for commodity n. For σ_D and σ_E, the term $(\sigma^2_E - \sigma^2_D)$ is cancelled out because we assume that σ_E is equal to σ_D.

In addition, we should note that the variables denoting domestic output, exports, and imports, $Y_{D,n,t}$, $Y_{E,n,t}$ and $Y_{I,n,t}$, in equations (3.22), (3.23) and (3.26)-(3.29) are expressed in terms of quantity or volume (i.e., in real terms). As already described, however, we use the domestic output value and export and import

[14] It could be argued that the standard deviation of $\varphi_{E,n,t}(p_{n,t})$ may be smaller than the standard deviation of $\varphi_{D,n,t}(p_t)$, given the fact that only a small number of factories export. Although there are no data for the export unit value for each commodity at the factory level, we checked the standard deviations of the log of the unit values for non-exporting factories and for exporting factories. We did not find any systematic difference between the standard deviations for these two groups. Therefore, we assume that the standard deviations of $\varphi_{E,n,t}(p_{n,t})$ and $\varphi_{I,n,t}(p_t)$ are equal to the standard deviation of $\varphi_{D,n,t}(p_t)$.

values for $Y_{D, n, t}$, $Y_{E,n,t}$ and $Y_{I,n,t}$, instead of quantity or volume due to data constraints. Therefore, for equation (3.22)', for example, we replace $Y_{D, n, t}$ and $Y_{E,n,t}$ with $NY_{D, n, t}$ and $NY_{E,n,t}$, respectively (NY denotes nominal values). We assume that $NY_{D, n, t}$ should be $Y_{D, n, t}$ multiplied by the average factory-level unit value and that $NY_{E,n,t}$ should be $Y_{E,n,t}$ multiplied by the unit value of Japan's exports. Therefore, equation (3.22)' can be rewritten as:

$$L_{S,E,n,t} = NY_{E,n,t} \frac{L_{S,D,n,t}}{NY_{D,n,t}} \exp\{(\theta_S + \theta_Y - 1)(\mu_E - \mu_D)\} \qquad (3.22)''$$

Similarly, we can rewrite equations (3.23) and (3.26)-(3.29) using $NY_{D, n, t}$, $NY_{E,n,t}$, $NY_{I,n,t}$, μ_E, μ_I, and μ_D.

Although we propose a way to calculate the factor contents of trade at the commodity level using our theoretical framework, it turns out to be extremely difficult to do so in practice. In order to calculate the factor contents of exports or imports, we have to match the unit value and the factor intensity information at the 6-digit commodity level of the CM with the export and import unit value information at the 9-digit commodity level of the Trade Statistics. In fact, as described in Section 3, we tried to match the data from both statistics for 1990. We were able to obtain unit value and factor intensity data for 635 commodities from the CM, but could match only slightly more than half of the 635 CM commodities with the export and/or import unit value information taken from the Trade Statistics because of differences in units. As a result, we were not able to calculate the factor contents of trade for many commodities when taking this approach. Although relatively many commodities could be matched with the Trade Statistics for some industries, such as the metals and transportation equipment industries, only an extremely limited number of commodities could be matched in the case general machinery and electrical and precision machinery, in which VIIT is most prominent in Japan and East Asia.[15]

Therefore, we take a different approach. We calculate the factor contents of trade at a more aggregated level, not at the commodity level. As equation (3.22)" shows, we need the ratio of the export unit value to the average of the unit value of domestic shipments, i.e., the term (μ_E - μ_D) on the right-hand side. Similarly, we need the ratio of the import unit value to the average of the unit value of domestic shipment (μ_I - μ_D) in order to calculate the factor contents of imports. We estimate the average ratio of the export unit value to the average of the unit value of domestic shipments and the average ratio of the import unit value to the average of the unit value of domestic shipments for ten broad industries in the following way. First, using the commodity-level shipment and quantity information taken from the CM for the years 2001-2004, we estimate the average difference between the log of the unit values for non-exporting factories and the log of the unit values for exporting factories by industry.[16] We use this average difference as the term (μ_E - μ_D) in the factor contents equations such as (3.22)". Second, using the HS 6-digit commodity-level export and import information taken from the Trade Statistics, we calculate the difference

[15] See Fukao et al. (2003), for example.

[16] As already mentioned in Section 3, for approximately 800 commodities out of the approximately 2,000 commodities in the CM quantity information is available. Therefore, the difference in the unit values for exporting and non-exporting factories are calculated using these 800 commodities with quantity information.

between the log of the export unit value and the log of the import unit value for each 6-digit commodity.[17] Then, we calculate the average difference between the log of the export unit value and the log of the import unit value for each broad industry, using the 6-digit-level trade values (exports + imports) as weights.[18] Third, using the difference between the export unit value and the domestic unit value and the difference between the export unit value and the import unit value, we calculate the difference between the log of the import unit value and the log of the domestic unit value (μ_I - μ_D), which is used to calculate the factor contents of imports. Fourth, for $L_{S, D, n, t}$, $K_{D, n, t}$, $L_{U, D, n, t}$, $Y_{D, n, t}$, we use the industry-level information from the JIP database, which provides various industry-level data for the 52 manufacturing industries. For $Y_{E,n,t}$ and $Y_{I,n,t}$, we use commodity-level information aggregated to the JIP industry level. Therefore, we calculate the factor contents of trade at the JIP industry level, using the JIP industry-level factor inputs, output values, and trade values, while using the average unit value differences at the broad industry level (ten industries).

The ratios between export and domestic unit values and between export and import unit values are shown in Table 7. The estimated factor contents of trade for 1990 and 2000 are shown in Tables 8 and 9, respectively. As can be seen in Table 7, export unit values tend to be lower than domestic unit values in industries such as food, textiles, wood, ceramics, and transportation equipment, while they tend to be higher than domestic unit values in industries such as chemicals, metals, and electrical and precision machinery. As Japan is a relatively rich country, it is reasonable to assume that products for domestic demand are of higher quality, i.e., they have a higher price, than products for export markets in some industries such as textiles or transportation equipment. However, in industries such as electrical machinery, Japan tends to supply high-quality parts and components for assembly in factories in other Asian countries. In such a case, the export unit value may be higher than the domestic unit value. As for export and import unit values, somewhat surprisingly, the former are lower than the latter in the machinery industries in 1990, although export unit values are higher than import unit values in all industries in 2000. This suggests that the international division of labor, or fragmentation, in the machinery industries in East Asia was not very advanced in 1990. However, by 2000, fragmentation of machinery production had become prevalent and Japan had become an exporter of high-quality (high priced) parts and components and an importer of low-quality (low priced) parts and components or finished goods.

Next, Table 8 shows the estimated amount of each production factor embodied in Japan's trade in 1990. Panel (a) shows the estimates taking account of VIIT, that is, in this table we take account of the unit value differences between exports, domestic shipments, and imports. Panel (b) shows the estimates not

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[17] For the log of the unit value of Japan's exports and imports, we calculate the log of the sum of exports (imports) in the 6-digit commodities in the Trade Statistics divided by the sum of the quantities in the 6-digit commodities in the Trade Statistics. It should be noted that in Japan's Trade Statistics, exports are recorded on an f.o.b. basis while imports are on a c.i.f. basis. Moreover, insurance and freight cannot be separated from the cost of imported goods. Therefore, if the value of imports is simply divided by the quantity of imports, import unit values will be overestimated. In order to mitigate this problem, we subtract 10 percent from all import values, a percentage that is approximately equivalent to the cost of insurance and freight, as suggested by Fukao et al. (2003), who estimate the difference between c.i.f. and f.o.b. values and report that the difference is 12.35 percent in the case of electrical machinery.

[18] In the case of exports, commodities for which the unit value can be calculated cover 74 percent and 75 percent of the total export value in 1990 and 2000, respectively. In the case of imports, commodities for which the unit value can be calculated cover 84 percent and 89 percent of the total import value in 1990 and 2000, respectively.

taking account of VIIT, that is, in this table we assume that the unit values of exports, domestic shipments, and imports are the same. In this case, the exponential term in equation (3.22)", for example, is assumed to take value 1. In Table 9, the factor contents of trade for 2000 are calculated using the factor intensities as of 2000 and using export and import information taken from the 2000 Trade Statistics. According to the estimates of the factor contents of trade, in 1990, the differences between the estimated factor contents taking account of VIIT and those not taking account of VIIT do not appear to be very large (Table 8). However, in 2000, the differences become much larger, which reflects the fact that differences between export and import unit values become much larger in 2000 than in 1990 (Table 9). That is, in 2000, the estimated number of non-production workers and capital stock embodied in Japan's net exports are much larger when we take account of VIIT than when we do not, and the estimated number of production workers embodied in Japan's net exports are much smaller (see panels (a) and (b) in Table 9). In 1990, these differences were much less pronounced. This result implies that Japan exports commodities of higher quality which are produced using more non-production workers and capital stock.

These results suggest that the measured impact of international trade on domestic factor markets differs substantially if we take account of quality differences in traded goods in the calculation of the factor contents of trade. In particular, reflecting the great advance in production fragmentation, Japan's net exports embody more skilled labor and capital when we take account of the quality of goods exported and imported. These results are also consistent with the argument put forward in previous studies such as that by Ahn et al. (2008) suggesting that the move to international outsourcing of intermediate inputs contributed to a shift in the demand for labor to skilled workers.

Table 7. Difference in average unit values

	2001-2004 Average		1990		2000	
	Census of Manufactures		Trade Statistics		Trade Statistics	
Industry	No. of commodities	Export - Domestic*	No. of commodities	Export - Import**	No. of commodities	Export - Import**
1 Food	32	-0.003	304	0.389	332	0.444
2 Textiles	45	-0.042	716	0.342	738	0.964
3 Wood	21	-0.111	184	0.402	209	0.985
4 Chemicals	176	0.067	915	0.238	943	0.380
5 Ceramics	28	-0.104	140	-0.045	149	0.723
6 Metals	111	0.122	504	0.149	581	0.348
7 General machinery	70	0.000	442	-0.104	448	0.444
8 Electrical & precision machinery	48	0.095	379	-0.281	434	0.277
9 Transportation equipment	32	-0.078	95	-0.367	101	0.089
10 Miscellaneous products	12	0.099	230	0.293	233	0.561

Notes: * Average value of 6-digit commodity-level "ln(unit value for exporting factories)-ln(unit value for non-exporting factories)" using 6-digit commodity-level shipments as weights.

** Average value of HS 6-digit commodity-level "ln(export unit value)-ln(import unit value)" using HS 6-digit commodity-level trade values as weights.

Table 8. Estimated factor contents of trade: Year 1990

(a) Year 1990: Taking account of VIIT

	Non-production workers (persons)			Production workers (persons)			Capital stock (mil. yen)		
Industry	Exports	Imports	Net Exports	Exports	Imports	Net Exports	Exports	Imports	Net Exports
1 Food	2,389	25,704	-23,315	10,872	129,850	-118,978	71,763	1,080,429	-1,008,666
2 Textiles	12,796	29,090	-16,295	87,214	206,518	-119,305	440,082	1,016,381	-576,299
3 Wood	3,458	17,077	-13,619	13,561	77,697	-64,136	201,748	658,057	-456,310
4 Chemicals	30,218	21,920	8,298	73,155	45,781	27,373	2,348,350	2,096,505	251,845
5 Ceramics	7,666	4,423	3,243	33,144	17,617	15,527	334,023	208,881	125,142
6 Metals	21,714	32,840	-11,126	69,489	90,083	-20,594	1,901,686	1,941,916	-40,230
7 General machinery	94,124	18,361	75,763	190,682	36,642	154,040	2,903,543	568,060	2,335,483
8 Electrical & precision machinery	185,381	41,343	144,037	465,083	101,551	363,532	7,213,664	1,637,625	5,576,039
9 Transportation equipment	60,067	14,318	45,749	192,394	38,591	153,803	5,982,567	1,056,065	4,926,502
10 Miscellaneous products	10,085	17,677	-7,592	42,720	91,246	-48,526	346,148	600,077	-253,930
Manufacturing total	427,898	222,754	205,144	1,178,312	835,576	342,736	21,743,574	10,863,997	10,879,577

(b) Year 1990: Not taking account of VIIT

	Non-production workers (persons)			Production workers (persons)			Capital stock (mil. yen)		
Industry	Exports	Imports	Net Exports	Exports	Imports	Net Exports	Exports	Imports	Net Exports
1 Food	2,391	28,968	-26,576	10,879	141,376	-130,497	71,756	1,067,382	-995,626
2 Textiles	12,804	29,270	-16,466	86,837	198,503	-111,666	439,528	1,004,730	-565,202
3 Wood	3,486	17,711	-14,225	13,592	78,539	-64,946	201,077	648,002	-446,925
4 Chemicals	29,872	22,573	7,299	73,120	45,836	27,284	2,326,581	2,146,795	179,786
5 Ceramics	7,761	4,454	3,307	33,219	17,640	15,580	334,928	209,204	125,724
6 Metals	21,217	33,008	-11,791	68,362	90,407	-22,045	1,896,126	1,943,167	-47,041
7 General machinery	94,124	18,273	75,851	190,682	36,906	153,777	2,903,543	569,302	2,334,241
8 Electrical & precision machinery	184,274	40,375	143,900	467,475	103,636	363,839	7,144,780	1,576,545	5,568,235
9 Transportation equipment	59,959	14,414	45,545	192,079	38,826	153,253	5,996,583	1,046,943	4,949,640
10 Miscellaneous products	9,845	18,528	-8,683	43,026	89,983	-46,957	343,825	608,031	-264,206
Manufacturing total	425,734	227,574	198,161	1,179,272	841,652	337,620	21,658,727	10,820,101	10,838,626

Table 9. Estimated factor contents of trade: Year 2000

(a) Year 2000: Taking account of VIIT

	Non-production workers (persons)			Production workers (persons)			Capital stock (mil. yen)		
Industry	Exports	Imports	Net Exports	Exports	Imports	Net Exports	Exports	Imports	Net Exports
1 Food	2,189	29,245	-27,056	11,112	164,939	-153,827	96,388	1,714,019	-1,617,631
2 Textiles	12,036	46,277	-34,241	81,023	349,405	-268,381	736,471	2,960,103	-2,223,632
3 Wood	3,193	20,326	-17,133	13,225	96,743	-83,518	290,869	1,157,002	-866,133
4 Chemicals	38,204	24,432	13,772	94,104	60,594	33,510	4,137,385	3,137,459	999,926
5 Ceramics	9,525	4,651	4,874	37,491	19,375	18,116	622,419	334,637	287,782
6 Metals	25,096	29,028	-3,932	79,905	85,072	-5,167	3,203,544	2,833,022	370,522
7 General machinery	118,764	21,689	97,075	249,130	47,507	201,622	5,950,907	1,109,560	4,841,347
8 Electrical & precision machinery	210,394	103,461	106,933	495,043	248,501	246,542	14,700,000	7,389,379	7,310,621
9 Transportation equipment	70,823	13,193	57,630	209,720	36,511	173,209	8,380,625	1,300,107	7,080,518
10 Miscellaneous products	10,029	18,709	-8,680	42,579	111,709	-69,130	524,022	959,488	-435,466
Manufacturing total	500,254	311,012	189,242	1,313,331	1,220,355	92,975	38,642,630	22,894,776	15,747,853

(b) Year 2000: Not taking account of VIIT

	Non-production workers (persons)			Production workers (persons)			Capital stock (mil. yen)		
Industry	Exports	Imports	Net Exports	Exports	Imports	Net Exports	Exports	Imports	Net Exports
1 Food	2,191	33,512	-31,321	11,119	181,720	-170,601	96,379	1,690,458	-1,594,079
2 Textiles	12,044	47,028	-34,984	80,674	315,008	-234,334	735,543	2,872,089	-2,136,546
3 Wood	3,218	21,971	-18,752	13,256	98,995	-85,739	289,902	1,119,584	-829,682
4 Chemicals	37,767	25,784	11,983	94,060	60,727	33,333	4,099,033	3,277,027	822,006
5 Ceramics	9,644	5,132	4,511	37,577	19,731	17,847	624,104	341,910	282,194
6 Metals	24,521	30,301	-5,780	78,609	87,688	-9,078	3,194,178	2,848,429	345,749
7 General machinery	118,764	22,137	96,627	249,130	46,073	203,057	5,950,907	1,099,256	4,851,651
8 Electrical & precision machinery	209,139	104,656	104,482	497,589	246,066	251,522	14,600,000	7,526,700	7,073,300
9 Transportation equipment	70,696	13,142	57,554	209,376	36,383	172,994	8,400,259	1,306,646	7,093,613
10 Miscellaneous products	9,791	20,933	-11,143	42,883	108,052	-65,169	520,506	990,125	-469,619
Manufacturing total	497,774	324,597	173,178	1,314,273	1,200,442	113,830	38,510,812	23,072,225	15,438,587

6. Conclusion

This paper aimed to contribute to the development of a new analytical framework for the empirical study of factor contents of VIIT. To this end, we first examined whether or not the widely used assumption of a positive relationship between unit values and human- or physical-capital intensities holds.

We found significant and stable relationships between factor intensities and unit values for many industries. As for the relationship between the unit value of a product and its white-collar labor intensity, the significant and positive relationship we found is important empirical evidence which supports the assumption widely used in theoretical models that commodities with higher prices are of higher quality and more human capital-intensive. On the other hand, we found that the relationship between the unit value of a product and its capital intensity is not always positive and that the relationship is significantly negative in some sectors. That is, we find that the widely used assumption that commodities with higher prices are more physical capital-intensive does not always hold.

After confirming that the relationship between unit values and factor intensities is robust, we estimated the factor contents of trade, taking account of differences in unit values of shipments by establishments in Japan, unit values of exports, and unit values of imports. We found that the number of non-production workers and the capital stock embodied in Japan's net exports were under-estimated when we did not take account of differences in unit values, i.e., differences in quality. In particular, the under-estimation is more serious for the year 2000 than for 1990. This reflects the increase in Japan's VIIT, which means that Japan is more likely to export commodities of higher unit values and import commodities of lower unit values, as a result of the rapid advance in production fragmentation in East Asia during the 1990s. The finding suggests that it is necessary to take account of the role of VIIT in order to correctly understand the implications of international trade for domestic factor markets.

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Appendix Tables

Appendix Table 1. List of Industries

2-digit	JIP industry classification	
1	8	Livestock products
1	9	Seafood products
1	10	Flour and grain mill products
1	11	Miscellaneous foods and related products
1	12	Prepared animal foods and organic fertilizers
1	13	Beverages
1	14	Tobacco
2	15	Textile products
3	16	Lumber and wood products
3	17	Furniture and fixtures
3	18	Pulp, paper, and coated and glazed paper
3	19	Paper products
3	20	Printing, plate making for printing and bookbinding
10	21	Leather and leather products
4	22	Rubber products
4	23	Chemical fertilizers
4	24	Basic inorganic chemicals
4	25	Basic organic chemicals
4	26	Organic chemicals
4	27	Chemical fibers
4	28	Miscellaneous chemical products
4	29	Pharmaceutical products
4	30	Petroleum products
4	31	Coal products
5	32	Glass and its products
5	33	Cement and its products
5	34	Pottery
5	35	Miscellaneous ceramic, stone and clay products
6	36	Pig iron and crude steel
6	37	Miscellaneous iron and steel
6	38	Smelting and refining of non-ferrous metals
6	39	Non-ferrous metal products
6	40	Fabricated constructional and architectural metal products
6	41	Miscellaneous fabricated metal products
7	42	General industry machinery
7	43	Special industry machinery
7	44	Miscellaneous machinery
7	45	Office and service industry machines
8	46	Electrical generating, transmission, distribution and industrial apparatus
8	47	Household electric appliances
8	48	Electronic data processing machines, digital and analog computer equipment and accessories
8	49	Communication equipment
8	50	Electronic equipment and electric measuring instruments
8	51	Semiconductor devices and integrated circuits
8	52	Electronic parts
8	53	Miscellaneous electrical machinery equipment
9	54	Motor vehicles
9	55	Motor vehicle parts and accessories
9	56	Other transportation equipment
8	57	Precision machinery & equipment
4	58	Plastic products
10	59	Miscellaneous manufacturing industries

Appendix Table 2. Relationship between factor intensity and unit production cost: Seemingly Unrelated Regression estimations without constraint

Equation number	Dependent variable	Food (1)	Textiles (2)	Wood (3)	Chemicals (4)	Ceramics (5)	Metals (6)	General machinery (7)	Electrical and precision machinery (8)	Transpor-tation equipment (9)	Miscellane-ous products (10)
(3.15)	dvlnWBratio	0.109***	0.089***	0.091***	0.161***	0.127***	0.058***	0.111***	0.113***	-0.008	0.277***
		(0.038)	(0.017)	(0.030)	(0.021)	(0.024)	(0.014)	(0.014)	(0.021)	(0.023)	(0.055)
(3.16)	dvlnKBratio	-0.132***	0.089***	0.073	0.148***	0.092***	-0.062***	0.055***	0.140***	0.055	0.155**
		(0.042)	(0.018)	(0.045)	(0.027)	(0.028)	(0.019)	(0.015)	(0.026)	(0.034)	(0.064)
(3.17)	dvlnMBratio	-0.241***	0.132***	0.013	-0.015	-0.024	-0.093***	0.088***	0.062***	0.040	0.133***
		(0.034)	(0.017)	(0.031)	(0.019)	(0.019)	(0.015)	(0.012)	(0.017)	(0.025)	(0.041)
(3.18)	dvlnBYratio	1.164***	0.896***	0.980***	0.972***	0.946***	1.067***	0.919***	0.943***	0.978***	0.842***
		(0.030)	(0.014)	(0.028)	(0.016)	(0.017)	(0.013)	(0.011)	(0.015)	(0.022)	(0.034)
	Number of observations	3006	6712	1942	4331	5515	8270	2267	1736	906	1074

Notes:
1. The dependent variables are factor intensities expressed in logarithmic form (deviation from the commodity-year mean).
2. Standard errors are in parentheses, with ***, ** and * indicating significance at the 1, 5 and 10 percent level, respectively.
3. Constant terms and year dummies are included, but estimated coefficients are not reported.
4. For the estimation, pooled data of factories with 30 or more employees in 1981, 1984, 1987, 1990 were used.

Appendix Table 3. Relationship between factor intensity and unit price: Seemingly Unrelated Regression estimations with constraint
--- Including multi-product establishments ---

Equation number	Dependent variable	Food (1)	Textiles (2)	Wood (3)	Chemicals (4)	Ceramics (5)	Metals (6)	General machinery (7)	Electrical and precision machinery (8)	Transpor-tation equipment (9)	Miscellane-ous products (10)
(3.15)	dvlnWBratio	0.084**	0.125***	0.073***	0.182***	0.124***	0.051***	0.111***	0.127***	-0.002	0.318***
		(0.037)	(0.016)	(0.028)	(0.021)	(0.025)	(0.014)	(0.013)	(0.019)	(0.022)	(0.058)
(3.16)	dvlnKBratio	-0.224***	0.077***	-0.117***	0.150***	-0.006	-0.116***	0.060***	0.175***	0.066**	0.147**
		(0.043)	(0.017)	(0.038)	(0.028)	(0.030)	(0.018)	(0.014)	(0.024)	(0.031)	(0.065)
(3.17)	dvlnMBratio	-0.205***	0.137***	-0.021	-0.056***	-0.034*	-0.179***	0.085***	0.054***	0.045*	0.073*
		(0.036)	(0.017)	(0.027)	(0.019)	(0.020)	(0.014)	(0.012)	(0.016)	(0.025)	(0.042)
(3.18)	dvlnBYratio	1.158***	0.893***	1.019***	1.019***	1.012***	1.135***	0.926***	0.942***	0.963***	0.924***
		(0.029)	(0.013)	(0.022)	(0.016)	(0.015)	(0.011)	(0.009)	(0.014)	(0.020)	(0.033)
	Number of observations	3450	8508	3042	5085	6255	9475	2675	2076	1187	1158

Notes:
1. The dependent variables are factor intensities expressed in logarithmic form (deviation from the commodity-year mean).
2. Standard errors are in parentheses, with ***, ** and * indicating significance at the 1, 5 and 10 percent level, respectively.
3. Constant terms and year dummies are included, but estimated coefficients are not reported.
4. For the estimation, pooled data of factories with 30 or more employees in 1981, 1984, 1987, 1990 were used.

Apendix Table 4. Relationship between factor intensity and unit price: Seemingly Unrelated Regression estimations with constraint
--- Including multi-product establishments ---

Equation number	Dependent variable / Explanatory variables	Food (1)	Textiles (2)	Wood (3)	Chemicals (4)	Ceramics (5)	Metals (6)	General machinery (7)	Electrical and precision machinery (8)	Transpor-tation equipment (9)	Miscellane-ous products (10)
(3.15)	dvlnWBratio										
	dvlnUV	0.085**	0.074***	0.070**	0.161***	0.117***	0.046***	0.111***	0.089***	-0.003	0.283***
		(0.038)	(0.016)	(0.028)	(0.021)	(0.026)	(0.014)	(0.013)	(0.018)	(0.022)	(0.059)
	lnTFP	0.111**	0.899***	0.057	0.125***	0.062	0.306***	0.177**	1.003***	0.202**	0.352***
		(0.049)	(0.045)	(0.064)	(0.046)	(0.038)	(0.036)	(0.069)	(0.085)	(0.088)	(0.124)
(3.16)	dvlnKBratio										
	dvlnUV	-0.256***	0.057***	-0.107***	0.131***	0.011	-0.113***	0.067***	0.136***	0.071**	0.164**
		(0.043)	(0.017)	(0.038)	(0.028)	(0.030)	(0.018)	(0.014)	(0.023)	(0.031)	(0.066)
	lnTFP	0.210***	0.325***	-0.455***	-0.027	-0.106**	0.155***	-0.117	1.211***	-0.046	-0.124
		(0.055)	(0.048)	(0.087)	(0.060)	(0.044)	(0.046)	(0.076)	(0.104)	(0.123)	(0.140)
(3.17)	dvlnMBratio										
	dvlnUV	-0.254***	0.080***	-0.024	-0.100***	-0.046**	-0.188***	0.081***	0.021	0.042*	0.034
		(0.035)	(0.016)	(0.026)	(0.019)	(0.020)	(0.014)	(0.012)	(0.015)	(0.025)	(0.043)
	lnTFP	0.560***	0.970***	0.380***	0.315***	0.390***	0.301***	0.157**	0.838***	0.141	0.235***
		(0.045)	(0.046)	(0.059)	(0.040)	(0.029)	(0.036)	(0.064)	(0.070)	(0.098)	(0.091)
(3.18)	dvlnBYratio										
	dvlnUV	1.197***	0.937***	1.021***	1.054***	1.019***	1.141***	0.929***	0.971***	0.964***	0.954***
		(0.029)	(0.012)	(0.022)	(0.016)	(0.015)	(0.011)	(0.009)	(0.013)	(0.020)	(0.033)
	lnTFP	-1.008***	-1.425***	-1.275***	-0.837***	-1.035***	-1.031***	-0.858***	-1.358***	-0.878***	-0.899***
		(0.042)	(0.037)	(0.061)	(0.040)	(0.030)	(0.034)	(0.058)	(0.062)	(0.093)	(0.076)
Number of observations		3376	8446	3023	5043	6190	9420	2656	2056	1174	1149

Notes: 1. The dependent variables are factor intensities expressed in logarithmic form (deviation from the commodity-year mean).
2. Standard errors are in parentheses, with ***, ** and * indicating significance at the 1, 5 and 10 percent level, respectively.
3. Constant terms and year and industry dummies are included, but estimated coefficients are not reported.
4. For the estimation, pooled data of factories with 30 or more employees in 1981, 1984, 1987, 1990 were used.

Appendix Table 5. Relationship between factor intensity and unit price: Seemingly Unrelated Regression estimations without constraint
--- Including multi-product establishments ---

Equation number	Dependent variable	Food (1)	Textiles (2)	Wood (3)	Chemicals (4)	Ceramics (5)	Metals (6)	General machinery (7)	Electrical and precision machinery (8)	Transpor-tation equipment (9)	Miscellane-ous products (10)
(3.15)	dvlnWBratio	0.039	0.126***	0.063**	0.173***	0.125***	0.049***	0.112***	0.124***	-0.002	0.314***
		(0.038)	(0.016)	(0.028)	(0.021)	(0.025)	(0.014)	(0.013)	(0.019)	(0.022)	(0.059)
(3.16)	dvlnKBratio	-0.212***	0.078***	-0.135***	0.137***	-0.017	-0.120***	0.061***	0.173***	0.071**	0.159**
		(0.043)	(0.017)	(0.039)	(0.028)	(0.030)	(0.018)	(0.014)	(0.024)	(0.032)	(0.065)
(3.17)	dvlnMBratio	-0.180***	0.139***	-0.010	-0.065***	-0.005	-0.181***	0.086***	0.050***	0.051**	0.062
		(0.036)	(0.017)	(0.027)	(0.019)	(0.020)	(0.014)	(0.012)	(0.016)	(0.025)	(0.042)
(3.18)	dvlnBYratio	0.945***	0.899***	0.918***	0.958***	0.848***	1.108***	0.932***	0.931***	0.990***	0.847***
		(0.036)	(0.014)	(0.032)	(0.019)	(0.022)	(0.014)	(0.012)	(0.015)	(0.025)	(0.038)
	Number of observations	3450	8508	3042	5085	6255	9475	2675	2076	1187	1158

Notes: 1. The dependent variables are factor intensities expressed in logarithmic form (deviation from the commodity-year mean).
2. Standard errors are in parentheses, with ***, ** and * indicating significance at the 1, 5 and 10 percent level, respectively.
3. Constant terms and year dummies are included, but estimated coefficients are not reported.
4. For the estimation, pooled data of factories with 30 or more employees in 1981, 1984, 1987, 1990 were used.