NBER WORKING PAPER SERIES

JAPANESE AND U.S. EXPORTS AND INVESTMENT AS CONDUITS OF GROWTH

Jonathan Eaton
Akiko Tamura

Working Paper 5457

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
February 1996

Original version prepared for presentation at the 5th Annual East Asian Seminar on Economics, June 15-17, 1994, Singapore. We thank seminar participants, in particular Toshihiko Kinoshita, Chong-Hyun Nam, and Bhanoji Rao, for comments. This paper is part of NBER's research program in International Trade and Investment. Any opinions expressed are those of the authors and not those of the National Bureau of Economic Research.

© 1996 by Jonathan Eaton and Akiko Tamura. All rights reserved. Short sections of text, not to exceed two paragraphs, may be quoted without explicit permission provided that full credit, including © notice, is given to the source.

NBER Working Paper 5457
February 1996

JAPANESE AND U.S. EXPORTS AND INVESTMENT AS CONDUITS OF GROWTH

ABSTRACT

We develop a simple model of the choice between exploiting a technology in another country via export and via direct foreign investment. The model points to the destination country's size, level of technological sophistication, and distance from the source as factors in the decision. Moreover, it suggests that the effects of these variables may not only be nonhomogeneous but nonmonotonic as well. We use the model as a basis for estimating Japanese and U.S. exports and DFI positions around the world. Consistent with the theory we find that the importance of DFI relative to exports grows with population, although, contrary to our theory, the elasticity of DFI, as well as exports, with respect to population is less than one. We find that distance tends to inhibit DFI much less than it inhibits exports, as our theory predicts. We find some tendency for Japanese exports to rise relative to DFI as countries become more advanced with U.S. exports and DFI exhibiting the opposite tendency. Taking population, per capita income, factor endowments, and distance into account, we find Japan to be more open to U.S. exports than any region in the world except East Asia.

Jonathan Eaton
Department of Economics
Boston University
270 Bay State Road
Boston, MA 02215
and NBER

Akiko Tamura
Department of Economics
Boston University
270 Bay State Road
Boston, MA 02215

1. Introduction

Japan and the United States are two major sources of technological innovation in the world economy. These two countries employ the largest number of research scientists and engineers among the OECD, and are major patentees of innovations throughout the world. (See, for example, Eaton and Kortum (1994).) The dissemination of this innovation around the world takes several forms. One is through the export of new products or of existing products at lower cost. Another is through direct foreign investment (DFI).

Our purpose here is to examine the roles of Japanese and United States exports and direct foreign investment as conduits of new technology. We first develop a theoretical model of technology diffusion in which one country, the source of innovation, develops new inputs into the production process at a regular rate. A fraction of these innovations are potentially useful in another country, which we call the destination. When these ideas are potentially useful the innovating firm can introduce them into the destination country either by producing them at home and exporting them there or by investing in the destination country to produce them locally. We compare the desirability of these alternatives. Our model identifies country characteristics that determine the extent to which innovators will use one method or the other to take advantage of their ideas abroad.

The analysis has several implications for the relationship between export and DFI levels, on the one hand, and characteristics of the destination country, on the other. One is that innovators will tend to exploit new ideas in smaller countries relatively more by exporting there, and in larger countries through DFI. For many parameter values our model implies that DFI will be most significant for middle income destination countries: At low levels of income market size is too small to support much DFI, while high wages in high income countries deter it. Factors that reduce the fixed cost of DFI, such as a high level of eduction, obviously encourage it, while factors that raise the opportunity cost of labor, such as a high natural resource endowment, discourage it.

Our model implies that bilateral trade and investment flows can be captured by a modified "gravity model" which relates exports and DFI to destination country characteristics reflecting market size, the cost of direct investment, the level of development, and transportation costs. In the second part of our analysis we estimate such a model for annual Japanese and U.S. exports and outward DFI to a panel of 72 countries during the period 1985-1990. Our aim is to identify characteristics of a country that are significant in determining how much Japan and the United States export and invest there.[1]

Several implications of the theoretical model find empirical support in the export and DFI patterns of both countries: First, distance, as a measure of transport costs, inhibits trade much more than it inhibits DFI. The negative effect of distance on trade exceeds that on DFI for both countries. Second, market size, as measured by population, favors DFI relative to investment: Population elasticities for both Japan and the U.S. exports and DFI are less than one but closer to one for DFI than for exports. Third, a high level of human capital, which we interpret as indicative of lower overhead investment costs, is associated with a larger DFI position (although human capital also has a positive, but less substantial, effect on exports from both countries as well).

While these results are common to both Japanese and U.S. trade and investment patterns, others are not. The prediction that the importance of DFI relative to exports peaks for middle income countries is satisfied by the United States but not by Japan. While population density, which we interpret as implying lower labor costs, is associated with more DFI from the United States, it brings in less from Japan. A possible explanation is that much Japanese DFI occurs to exploit natural resources that are processed for export to Japan (a possibility not captured by our theoretical model).

We estimate the model both with and without regional effects. Except for the role of distance, the basic implications are not very sensitive to the inclusion of regional effects. We do not undertake a lengthy discussion of regional trade and investment patterns here, which was the purpose of Eaton and Tamura (1994). One finding that is worth reporting, however, is that, correcting for distance and other national features, Japan imports more from the United States than any

[1]Leamer (1984) is the standard reference on the empirical implementation of factor endowments theory to trade flows. Helpman (1987) applies a model of imperfect competition and scale economies to the estimation of trade flows. Our analysis here combines elements of these two approaches. Less work has been done on the empirical specification of investment flows. Mundell (1957), Purvis (1972), and Markusen (1983) model the relationship between trade and investment flows. Helpman (1984) and Markusen (1984) provide models of direct foreign investment. The analysis here builds on earlier empirical work of Eaton and Tamura (1994), who analyze regional patterns of Japanese and U.S. trade and investment flows. The current paper develops a theoretical framework for modeling trade and investment flows as well as pursuing an empirical analysis. Moreover, different issues are considered. In particular, here we examine the role of distance and of potential nonlinearities in the relationship between trade and investment, on the one hand, and the level of development, on the other.

other region of the world except East Asia.

We present our theoretical framework in Section 2. Section 3 reports our results on Japanese and U.S. exports and DFI positions. We offer some conclusions in section 4.

2. A Model of Trade, Investment, and Growth

Our theoretical model focuses on two countries. One, which we call the source, constantly generates innovations for production. The other, the destination, eventually adopts these innovations, but with a lag. The number n of innovations available in the source summarizes the state of technology there, while the size of the subset m of these innovations available to the destination summarizes its state of technology. We first describe the equilibrium at any moment when m and n are given and then turn to what happens as m and n grow over time.

2.1. The Static Equilibrium

At any moment the source country can produce a homogeneous, costlessly-tradable final output (which serves as numeraire) with a variety of n intermediate inputs according to the standard Dixit-Stiglitz (1977) production relationship:

$$Q = [\int_0^n x_i^\rho di]^{1/\rho} \quad \rho \in (0,1).$$

Here Q represents final output and x_i denotes the amount of input i. The implied cost of producing an amount Q is:

$$C(p,Q) = \left[\int_0^n p_i^{\frac{\rho}{\rho-1}} di\right]^{\frac{\rho-1}{\rho}} Q$$

where p_i is the price of input i. The destination has the technology to use a subset m of these inputs to produce the same final output. Intermediates are produced with one unit of labor in either country.

The technology to produce each intermediate i is owned by a firm in the source, which takes the wages in each country, w_s and w_d in the source and destination respectively, as given, as well as the prices charged by other input producers in either country. Inputs can be exported, but exporting one unit of any input requires the use of τ workers in the exporting country. Owners of individual input technologies face the decision of where to produce. Inputs in principle can be produced in each market for local production or in one market to service both (or through some combination of the two). To make the analysis less taxonomic we will assume that exporting inputs from d to s is so costly that it is unprofitable. (As the reader will see, even with simple assumptions things get complicated.) Hence the $n - m$ inputs that have not been absorbed into the destination's technology are solely produced in s for use in s. Owners of the m inputs common to both countries must decide whether to serve the destination market by exporting there or by producing there. Exporting a unit requires τ country s workers while producing in d at all requires employing F country d overhead workers on an ongoing basis.

Since producers of all inputs, whether they export or produce locally, set the prices of their individual inputs taking all other input prices as given, to maximize profit individual producers will charge a markup $\frac{1}{\rho}$ over marginal cost. Hence producers selling in the local market of the source country will always set a price $p_s = \frac{w_s}{\rho}$ while those exporting to country d will set a c.i.f. price $p_X = \frac{w_s(1+\tau)}{\rho}$ and those producing locally in country d will charge $p_D = \frac{w_d}{\rho}$.

2.1.1. The source

Since the source produces all of its own inputs, we can take care of it quickly. From the cost function implied by the production function, zero-profits in the production of the final (numeraire) good require that $p_s = n^{(1-\rho)/\rho}$ or a wage in the source country of:

$$w_s = \rho n^{(1-\rho)/\rho}. \tag{2.1}$$

Hence as n grows, allowing for greater division of labor in s, so does the wage there.

2.1.2. The destination

In the destination country, however, there are two potential sources of input supply, so that things are more complicated.

Denote by λ^D the fraction of the m inputs that have been absorbed into d's technology that producers choose to produce in country d (so that the remaining $1 - \lambda^D$ are exported from s). The cost of producing a unit of final output in d is then:

$$c_D = \{m[(1 - \lambda^D)v_X + \lambda_D v_D]\}^{(\rho-1)/\rho}$$

where $v_X = p_X^{\rho/(\rho-1)} = (1+\tau)^{\rho/(\rho-1)}/n$ and $v_D = p_D^{\rho/(\rho-1)}$. For country d to compete in the world market for the final good requires that local production be competitive, or that:

$$1 = c_D = \{m[(1-\lambda^D)v_X + \lambda^D v_D]\}^{(\rho-1)/\rho}. \qquad (2.2)$$

In order for any domestic production of inputs to occur it must be the case that the marginal cost of producing locally is less than that of importing (since the first requires a fixed cost while the second does not). Thus $v_D > v_X$. Hence the zero-profitability condition (??) implies a negative relationship between λ^D and v_D.

The profit earned from producing an input in country d is:

$$\pi_D = (1-\rho)\{m[(1-\lambda^D)v_X + \lambda^D v_D]\}^{-1/\rho} v_D Q_d - w_d F,$$

where Q_d is the amount of the final good produced in country d, while the profit earned from exporting to country d is:

$$\pi_X = (1-\rho)\{m[(1-\lambda^D)v_X + \lambda^D v_D]\}^{-1/\rho} v_X Q_d.$$

For $\lambda_D \in (0,1)$, then, requires that $\pi_X = \pi_D$ or, incorporating the zero-profitability of final production condition (??), that:

$$v_D - v_X = \frac{\rho v_D^{(\rho-1)/\rho} F}{(1-\rho)Q_d}. \qquad (2.3)$$

If the left-hand side of (??) exceeds the right then $\lambda_D = 1$ while if the right-hand side exceeds the left then $\lambda_D = 0$.

If there are L_d workers available to direct foreign investors in country d then $L_d - \lambda^D mF$ of them will be available for final production of inputs. These will divide themselves evenly among the $\lambda^D m$ inputs that are locally produced. Hence the amount of each locally produced input will be $x_D = L_d/(\lambda^D m) - F$. The production of final output in country d is therefore:

$$Q_d = \frac{(m\lambda^D)^{(1-\rho)/\rho} L_d - (m\lambda^D)^{1/\rho} F}{[1-(1-\lambda^D)mv_X]^{1/\rho}}. \qquad (2.4)$$

Hence equation (??) determines w_s, (and hence $p_s = \frac{w_s}{\rho}$, $p_X = \frac{w_s(1+\tau)}{\rho}$ and $v_X = p_X^{\rho/(\rho-1)}$) as a function of n, the state of technology in s, as well as the production parameter ρ and the transport cost τ. Equations (??), (??), and (??) then determine the wage in country d, w_d (and thus p_D and v_D), the fraction of inputs produced in d, λ^D, and output in country d, Q_d, as functions of the wage in s, the labor force in d, L_d, the number of inputs that can be used in d, m, and the production function parameter ρ and the number of overhead workers F.

Solving the four equations, the equilibrium fraction of inputs produced locally turns out to be:

$$\lambda^D = \min[\tilde{\lambda}^D, 1],$$

where:

$$\tilde{\lambda}^D = \frac{x}{2\rho}\left[-1+\sqrt{1+\frac{4(1-\rho)\rho}{x}\frac{L}{Fn\sigma}}\right] \tag{2.5}$$

and where $\sigma = m/n$, the fraction of inputs that country d can use, $x = \frac{1-\sigma\tau'}{\sigma\tau'}$, and $\tau' = (1+\tau)^{\rho/(\rho-1)}$. Note that λ^D increases with the ratio of the labor force to the required number of overhead workers $L/(Fn\sigma)$ and with the transport cost τ and decreases with the fraction of inputs σ that country d can use.

2.2. Dynamics

Our concern is with a situation in which the countries grow over time. We model this as the process of n and m growing at a common rate g.[2] Obviously if the number of overhead workers required to produce a good locally remains constant, without any growth in the labor force eventually almost all inputs in the destination country will be imported. Since the ratio of the volume of trade to output seems to have remained roughly constant over time, even as the division of labor has increased, technical progress must have occurred in overhead as well. To allow for a steady-state in which the proportion of trade to production remains constant even as the world economy grows we let the fixed cost of direct foreign investment fall in proportion as the number of available inputs increases. We also want to allow for the possibility that more advanced countries, *i.e.*, destination countries that are better able to absorb new foreign technologies, might also provide overhead services more efficiently. To capture these effects we set $F = f/(\sigma^\mu n)$, where

[2]Krugman (1979) provides a growth model in which the steady state has this property. Here, as in Krugman, new products erupt in the source country spontaneously, and trickle down to the destination. Our model could accommodate an endogenous R&D process as in Grossman and Helpman (1991), but since our focus is on how technologies are transmitted rather than how they are developed we treat innovation as exogenous.

f is a positive constant and μ is a (presumably positive) parameter capturing the effect of relative productivity on the efficiency with which overhead services can be provided.

Incorporating this expression for F into (??) we get a share of foreign direct investment (if it is interior) of:

$$\tilde{\lambda}^D = \frac{x}{2\rho}\left[-1+\sqrt{1+\frac{4(1-\rho)\rho}{x}\frac{L\sigma^{\mu-1}}{f}}\right]. \tag{2.6}$$

which is independent of the current state of technology n. Under these assumption output in the two countries will grow at a common rate $(1-\rho)g/\rho,$. with the relative productivity of the destination depending on σ. The fraction of inputs produced locally will remain constant over time.

It remains the case that countries that are larger relative to the fixed cost parameter f, and countries that are more expensive to export to, will have relatively more investment. Depending on the parameter μ, however, the share of products produced locally might rise or fall with the destination's relative productivity as reflected by the ratio σ.

To illustrate what the model implies for the relationship between a country's ability to absorb technology and how much DFI it attracts relative to exports, the table below reports values of λ^D and the ratio of exports to output (X/Q) for values of σ between .1 and 1 (at intervals of .1). In our base case, reported in column (1), $L/f = 5$, $\rho = .75$, $\tau = .05$, and $\mu = 2$. Our choice of μ implies that overhead requirements fall more than in proportion to the number of inputs that the country can use. The chosen values of ρ implies an elasticity of substitution between inputs of 4 and a markup over the marginal cost of production of 33 per cent. Transport costs are 5 per cent of the marginal cost of production in the source. Given these other parameter values, our choice of the ratio of the fixed cost parameter to the labor force implies a ratio of overhead to production workers of between 5 and 10 per cent.

We also report the implications of (1) dropping μ to 1 (so that overhead requirements in more advanced countries is exactly inversely proportional to their ability to adopt inputs), (2) dropping ρ to .5 (so that the elasticity of substitution between inputs is 2), (3) raising τ to .1, and (4) doubling the labor force.

σ	*base* λ^D	$\frac{X}{Q}$	$\mu = 1$ λ^D	$\frac{X}{Q}$	$\rho = .5$ λ^D	$\frac{X}{Q}$	$\tau = .1$ λ^D	$\frac{X}{Q}$	$L/f = 10$ λ^D	$\frac{X}{Q}$
.1	.12	.08	1.00	0	.25	.07	.12	.07	.25	.07
.2	.24	.13	1.00	0	.47	.10	.24	.11	.47	.09
.3	.34	.17	.99	0	.66	.10	.35	.15	.64	.09
.4	.43	.20	.92	.03	.80	.08	.44	.17	.77	.08
.5	.49	.22	.84	.07	.89	.05	.51	.18	.84	.07
.6	.53	.25	.77	.12	.93	.04	.56	.20	.88	.06
.7	.54	.28	.70	.18	.91	.06	.59	.22	.87	.08
.8	.53	.33	.62	.27	.85	.12	.60	.24	.83	.11
.9	.49	.40	.53	.37	.72	.24	.59	.28	.76	.19
1.0	.42	.50	.41	.50	.45	.52	.55	.33	.63	.32

Several things are worth noting:

First, a doubling of the population raises the fraction of inputs produced locally, with more effect in richer countries. The model thus predicts that DFI will tend to increase more than in proportion to the destination country's size while exports will increase in less than proportion. At the same time an increase in population acts to reduce the fraction of exports to output. Hence the model predicts nonhomogeneity in the relationship between country size, on the one hand, and exports and DFI, on the other, with an increase in country size leading to a less than proportional increase in exports but a more than proportional increase in DFI.

Second, the relationship between the destination's ability to absorb technology and the extent to which source country innovators will exploit their ideas through direct foreign investment can be nonmonotonic. In all but the case in which $\mu = 1$ it is an "inverted U" relationship, with the fraction of inputs provided through investment peaking for middle income countries. The share of direct foreign investment rises between the poorest and middle income countries since the fixed cost falls, but for richer countries this effect is overshadowed by the higher labor costs in the more advanced country. When $\mu = 1$ the first effect is inoperative so that only the second manifests itself, so that the share of inputs provided through DFI falls as σ rises.

Third, despite the nonmonotonicity in the relationship between the fraction of inputs provided through DFI and output, exports tend to rise with σ. The reason is that as σ rises so does the wage and the cost of production in the destination country relative to the cost of production in the source. Since the elasticity of substitution between inputs exceeds one, an increased relative cost of production and, hence, through the fixed mark-up, an increased price, implies a lower expenditure on the input. Hence a poor country tends to use a much larger amount of a domestically produced input, relative to an imported input, than richer country. Notice that when the elasticity of substitution falls to 2 the tendency of exports to rise with σ is much less pronounced.

Fourth, doubling transport costs, not surprisingly, reduces exports and raises the fraction of inputs produced locally. The effect is greater for richer countries. The model predicts, then, that innovators will tend to exploit their ideas in more distant countries via direct foreign investment and in closer countries through export.

3. Japanese and U.S. Exports and DFI

We use the model as a basis for examining Japanese and U.S. exports and outward DFI positions with a balanced panel of 72 countries, using annual data for the period 1985-1990. Our model implies that exports to a country and DFI positions in that country will be determined by: (i) the labor force available for employment by direct foreign investors in that country relative to the cost of investing there, (ii) the country's ability to adopt technologies from the source country, and (iii) the cost of exporting goods there.

3.1. Econometric Specification and Variables

To capture the effect of the country's available labor force relative to investment costs we relate Japan's and the United States's exports X_{it} and outward DFI O_{it} at time t to partner i's population POP_{it}. Our model implies that exports and DFI are potentially nonhomogeneous is size. Hence we introduce a specification that allows for nonhomogeneity. We capture the effect of a country's ability to absorb technology from the source through income per capita YPC_{it}. Since our model implies that the effect of σ on the relative importance of DFI and exports might be nonmonotonic, we introduce both a linear and quadratic measure of income per capita. Also, the ability of a country to make use of Japanese and U.S. ideas might depend on its factor endowments. We use the destination's population density

DEN_{it} as an inverse measure of natural resource endowments and a measure of the average years of schooling per worker HK_i to capture human capital.[3] Finally we use distance d_i from Japan or the United States to capture transport costs.[4] Different regions of the world might have unobserved characteristics (such as different policies toward imports and direct foreign investment) other than those which we have taken into account. Hence in one set of estimates we include dummy variables for the region of the destination country δ_{Ri} (assigned as indicated in Table 1A). We also include dummy variables to take into account systematic effects of time δ_T.

As the subscripts indicate, we have annual data for the variables POP, YPC, and DEN. Our measure of human capital, taken from Kyriacou (1991), is available only at five year intervals. Hence we use the measure for 1985 for all years.[5] Table 1B indicates sources of data.

Our specification embodies elements of both the standard gravity and factor endowments specifications of trade patterns extended to explain direct foreign investment positions as well as trade flows.[6] In contrast to these approaches, our model implies potential nonhomogeneity in the relationship between our dependent and explanatory variables. To accommodate these, we assume that for each dependent variable $V, V = X, O$, the explanatory variables are linear homogeneous in $a_V + V_{it}$, where a_V is a threshold parameter that we estimate. A positive value of a_V implies that the function of the explanatory variables explaining V must achieve a minimum threshold value before strictly positive values of V occur. A negative value of a_V means that a minimum level of V occurs independently of

[3]These measures also might reflect aspects of labor force availability relative to the cost of investment. A high level of human capital might, other things equal, reduce the cost of overhead, while a high natural resource endowment might reduce the labor force available for producing in the manufacturing sector (to which our model is more appropriate).

[4]Distances are between major cities. Table A2 reports the cities chosen and the distances between them for the cities in our sample. Distance might also raise the overhead requirement for DFI.

[5]Kyriacou (1991) constructs a measure of the average level of human capital from official data on schooling using a perpetual inventory method. We thank Mark Spiegel for making the data available to us.

[6]Deardorff (1984) discusses the "gravity" approach to modelling trade flows econometrically. It has its origins in the work of Tinbergen (1962) and Poyhonen (1963). The framework has recently been applied to regional trade issues by Frankel and Wei (1993). Drysdale and Garnaut (1982) provide a very thorough survey of the approach. Leamer (1974), as we do here, estimates a model that encompasses the factor-endowments and gravity approaches.

the explanatory variables.

For Japan and the United States separately, then, we estimate the equations:

$$\begin{aligned} V_{it} &= \max[-a_V + C_V POP_{it}^{\alpha_V} YPC_{it}^{\beta_V + \beta'_V \ln YPC_{it}} DEN_{it}^{\gamma_V} HK_{it}^{\epsilon_V} d_i^{\eta_V} \\ &\quad \exp(D_T \delta_{VT} + D_R \delta_{VR} + u_{it}), 0] \end{aligned}$$

for $V = X, O$. Here u_{Vit} is a normal error term associated with dependent variable V and δ_{VT} is the column vector of coefficients of dummy variables for time and δ_{VR} is the column vector of dummy variables for region. For each dependent variable V we estimate the intercept a_V, the constant C_V, the population coefficient α_V, the per capita income coefficients β_V and β'_V, the density coefficient γ_V, the human capital coefficient ϵ_V, and the distance coefficient η_V. Note that we allow for a nonconstant elasticity of income per capita.

We estimate the equations by maximum likelihood. To derive the maximum likelihood function we rearrange this relationship and take natural logarithms of each side to obtain:

$$\begin{gathered} \ln(a_V + V_{it}) = \\ C_V + \alpha_V \ln POP_{it} + \beta_V \ln YPC_{it} + \beta'_V (\ln YPC_{it})^2 + \gamma_V \ln DEN_{it} + \epsilon_V \ln HK_i + \eta_V d_i + \\ D_{VT} \delta_{Tt} + D_{VR} \delta_R + u_{Vit} \equiv \\ Z'_{Vit} \theta_V + u_{it} \end{gathered}$$

The density function for V_{it} is:

$$f(V_{it}) = f(u_{it}) \left| \frac{\partial u_{it}}{\partial V_{it}} \right| = f(u_{it}) \frac{1}{V_{it} + a_V}.$$

We assume that $u_{it} \sim N(0, \sigma^2)$. Hence,

$$f(V_{it}) = \frac{1}{a_V + V_{it}} \cdot \frac{1}{(2\pi\sigma^2)^{1/2}} \exp\left\{ -\frac{[\ln(V_{it} + a_V) - Z'_{it}\theta_V]^2}{2\sigma^2} \right\}$$

and the log-likelihood function is:

$$\ln L(V, Z'; \theta_V, a_V) = \{-\ln(V_{it} + a_V) - \frac{1}{2}(\ln 2\pi + \ln \sigma^2) - \frac{1}{2\sigma^2}[\ln(V_{it} + a_V) - Z'_{it}\theta_V]^2\}$$

The maximum likelihood estimates of a_V and θ_V maximize $\ln L(V, Z'; \theta_V, a_V)$.

Tables 1 and 2 report the estimated equations for Japan and the United States, respectively. The numbers in italics below the estimated coefficients are Eicker-White standard errors (See White 1982). Defining $\pi_V = \{\theta_V, a_V\}$ as the vector of parameters, these are the square roots of the diagonal elements of the matrix:

$$Var(\pi_V) = A^{-1}(\pi_V)B(\pi_V)A^{-1}(\pi_V)$$

where:

$$A(\pi_V) = \frac{1}{NT}\sum_{t=1}^{T}\sum_{i=1}^{N}\frac{\partial^2 \ln f(V_{it}, Z'_{it}, \theta_V, a_V)}{\partial\pi_V \partial\pi'_V}$$

$$B(\pi_V) = \frac{1}{NT}\sum_{t=1}^{T}\sum_{i=1}^{N}\left[\frac{\partial \ln f(V_{it}, Z'_{it}, \theta_V, a_V)}{\partial\pi_V} \cdot \frac{\partial \ln f(V_{it}, Z'_{it}, \theta_V, a_V)}{\partial\pi'_V}\right].$$

Because of the intercepts a_V, the coefficients $\alpha_V, \beta_V, \beta'_V, \gamma_V$,ϵ_V and η_V converge only asymptotically to the elasticity of the dependent variable with respect to the corresponding dependent variable as the dependent variable approaches infinity. Tables 3 reports the actual elasticities calculated at the mean values of the dependent variables.

3.2. Results

We discuss effects of population, per capita income, factor endowments, and distance in turn.

3.2.1. Population

Consistent with the theory we find that population has a nonhomogeneous effect both on exports and DFI. Moreover, consistent with the model we find that the population elasticity for exports tends to be lower than that for DFI, so that large countries do tend to receive more DFI than exports compared with small countries. While our estimates population elasticities for exports are less than one, as our theory would predict, they are also less than one for DFI, in contrast with what our theoretical model predicted. The results thus suggest that larger countries are more closed overall than smaller countries, but relatively less closed to DFI than to exports.

3.2.2. Per Capita Income

The U.S. results confirm the model's prediction of an elasticity of exports with respect to the level of development above one. The elasticity for Japan is very close to one, however. Our estimates imply that increases in relative per capita income increase DFI at an accelerating rate. The effect on exports differs between the Japan and the United States, however. The effect of income per capita on imports from Japanese also tends to accelerate while its effect on imports from the U.S. is sensitive to the inclusion of region dummies. Figures 1 and 1a illustrate (for Japan) and 2 and 2a (for the United States) the effects of increases in the destination country's income per capita on DFI and exports from the two countries, with and without the inclusion of regional dummies. A rough impression is that, for Japan, exports tend to replace DFI as income grows, with the opposite the case for the United States. This result suggests that Japan's cost of DFI tends to be relatively lower in poor countries compared with the United States.

3.2.3. Factor Endowments

We find that increased density acts to increase exports from both countries. An explanation is that, given per capita income, countries with less in the way of natural resources absorb more technology from the two countries, and hence import more. We find less tendency for more densely populated countries to absorb more DFI. In the case of Japanese DFI the relationship is negative. One explanation, not accounted for in our theoretical model, is that some Japanese DFI is undertaken to exploit natural resources.

Increases in human capital have a significant effect on both exports and DFI from both countries, suggesting that once other factors are taken into account countries with more human capital tend to absorb more technology from Japan and the United States. Moreover, the elasticity with respect to DFI is much larger than with respect to exports. A plausible explanation consistent with our model is that a high level of human capital reduces the fixed cost of undertaking DFI.

3.2.4. Distance

The effects of distance on exports and DFI, unlike the effects of most of our other explanatory variables, are quite sensitive to the inclusion of regional effects. This sensitivity is not surprising given the multicolinearity between the two. We find, however, that distance always has an inhibiting effect on exports (as a standard gravity specification would predict). Moreover, as our model would predict, distance reduces trade more than it reduces DFI. Except for the case of Japan, when regional dummies are included, we find that distance also tends to inhibit DFI, but by less than it inhibits exports. Hence Japan and the United States tend to trade relatively more close by and to invest relatively more far away.[7]

3.2.5. Regional Effects

Eaton and Tamura (1994) discuss the regional concentration of Japanese and U.S. trade and DFI patterns. This earlier work did not include distance as a separate explanatory variable, incorporating the effect of distance through the regional effects. A primary finding there was that, correcting for size, per capita income, and factor endowments, Japan imported more from the United States than the typical country in western Europe. Our results here strengthen this finding significantly. We find that, once distance as well as these other factors are taken into account, Japan imports more from the United States than any other region except East Asia, including not only Western Europe but North and Central America as well. We still find Japan to be more closed than Western Europe to U.S. DFI, but only slightly so. We also continue to find Oceania and East Asia to be highly open to both exports and DFI from both countries.

4. Conclusion

Japan and the United States are not only the two largest economies in the world, measures of research activity and patenting indicate that they are also the two largest sources of technological innovation in the world. Exports and DFI are two major conduits for transferring technology abroad.

In this paper we have developed a simple model of the decision whether to exploit a technology abroad via export or via direct foreign investment. The model points to country size, technological sophistication, and distance as important factors. Moreover, it suggests that the effects of these variables may not only be nonhomogeneous but nonmonotonic as well.

[7]Brainard (1993a,1993b) provides evidence on the role of distance in trade and DFI decisions from firm-level data. She also finds a tendency for firms to rely more on domestic production than on exports to serve more distant markets.

We use the model as a basis for specifying a model of Japanese and U.S. export and DFI patterns around the world. The implications of some but not all aspects of the model are confirmed. We do find, for example, that the importance of DFI relative to exports tends to grow with country size, but that DFI as well as exports tend to increase less than in proportion to country size while our model predicts that DFI should increase more than in proportion. Consistent with our model we also find that distance tends to inhibit DFI much less than it inhibits exports. Both Japan and the United States tend to export more relatively close by and to invest relatively more far away. The model predicts that the relationship between exports and DFI, on the one hand, and a country's ability to absorb technology, on the other, can be very nonmonotonic. We find some tendency for Japanese exports to rise relative to DFI as countries become more advanced with U.S. exports and DFI exhibiting the opposite tendency.

A striking finding, reinforcing a major result in Eaton and Tamura (1994), is that Japan is relatively open to U.S. exports compared with other regions of the world, taking into account size, income, and factor endowments. Here we find that taking distance into account sharply accentuates this result: Once distance as well as these other factors are corrected for Japan is more open to U.S. exports than any region except East Asia.

Our empirical work has focussed very narrowly on exports and DFI, taking the background of innovation and diffusion as given. A task for future research is the integration of the issues considered here with an analysis of the factors determining the rate of innovation in the world economy.

References

Brainard, S. Lael. 1993a. "An Empirical Assessment of the Proximity-Concentration Tradeoff between Multinational Sales and Trade," *NBER Working Paper No. 4580,* Cambridge, MA.

Brainard, S. Lael. 1993b. "An Empirical Assessment of the Factor Proportions Explanation of Multinational Sales," *NBER Working Paper No. 4583,* Cambridge, MA.

Deardorff, Alan V. 1984. "Testing Trade Theories and Predicting Trade Flows", in *The Handbook of International Economics*, edited by Ronald W. Jones and Peter B. Kenen. Amsterdam: North Holland.

Dixit, Avinash and Joseph E. Stiglitz. 1977. "Monopolistic Competition and Optimum Product Diversity," *American Economic Review*, 67: 297-308.

Drysdale, Peter and Ross Garnaut. 1982. "Trade Intensities and the Analysis of Bilateral Trade Flows in a Many-Country World: A Survey," *Hitotsubashi Journal of Economics*, 22: 62-84.

Eaton, Jonathan and Samuel Kortum. 1994. "International Patenting and Technology Diffusion." *NBER Working Paper* Cambridge, MA.

Eaton, Jonathan and Akiko Tamura. 1994. "Bilateralism and Regionalism in Japanese and U.S. Trade and Direct Foreign Investment Patterns," *Journal of the Japanese and International Economies.*

Frankel, Jeffrey A. and Shang-Jin Wei. 1993. "Trade Blocs and Currency Blocs" *NBER Working Paper No. 4335,* Cambridge, MA.

Grossman, Gene M. and Elhanan Helpman. 1991. *Innovation and Growth in the World Economy.* Cambridge, MA: MIT Press.

Helpman, Elhanan. 1984. "A Simple Theory of International Trade with Multinational Corporations," *Journal of Political Economy*, 92: 451-471.

Helpman, Elhanan. 1987. "Imperfect Competition and International Trade: Evidence from Fourteen Industrial Countries," *Journal of the Japanese and International Economies*, 1: 62-81.

Krugman, Paul R. 1979. "A Model of Innovation, Technology Transfer, and the World Distribution of Income," *Journal of Political Economy*, 87: 253-266.

Kyriacou, George.1991. "Level and Growth Effects of Human Capital," C.V. Starr Center Working Paper No. 91-26, New York University.

Leamer, Edward E. 1974. "The Commodity Composition of International Trade in Manufactures," *Oxford Economic Papers.* C, 26: 350-374.

Leamer, Edward E. 1984. *Sources of International Comparative Advantage.* Cambridge, MA: MIT Press.

Markusen, James R.1983. "Factor Trade and Commodity Trade as Complements," *Journal of International Economics*, 15: 341-356.

Markusen, James R. 1984. "Multinational, Multi-Plant Economies, and the Gains from Trade," *Journal of International Economics*, 16: 205-226.

Mundell, Robert A. 1957. International Trade and Factor Mobility," *American Economic Review*, 47: 321-337.

Poyhonen, Pentti.1963. "A Tentative Model for the Volume of Trade Between Countries," *Weltwirtschaftliches Archiv*, 90: 93-99.

Purvis, Douglas D. 1972. "Technology, Trade, and Factor Mobility," *Economic Journal*, 82: 991-999.

Summers, Robert and Alan Heston.1991. "The Penn World Tables (Mark 5): An Expanded Set of International Comparisons, 1950-1988" *Quarterly Journal of Economics*, 106: 327-369.

Tinbergen, Jan. 1962. *Shaping the World Economy: Suggestions for an International Policy* (New York).

White, Halbert . 1982. "Maximum Likelihood Estimation of Misspecified Models," *Econometrica*, 50: 1-26.

TABLE1
JAPAN: TRADE AND INVESTMENT EQUATIONS

$\ln(a + V) = \max[Z'b + u, \ln a]$

Maximum Likelihood, Tobit Estimates

	V	Export	Export	DFI out	DFI out
	Observation #	432	432	432	432
	Log likelihood	-3015.62	-3098.43	-2749.42	-2906.23
	a	-2.428	-2.713	1.484	2.121
		0.266	*0.153*	*0.076*	*0.082*
Z	C	21.746	8.920	21.386	6.334
		3.842	*3.957*	*7.568*	*9.634*
	ln(POP)	0.716	0.699	0.837	0.779
		0.025	*0.032*	*0.048*	*0.074*
	ln(YPC)	-6.352	-3.200	-6.985	-2.965
		0.879	*0.914*	*1.728*	*2.177*
	(ln(YPC))^2	0.409	0.234	0.417	0.210
		0.048	*0.050*	*0.097*	*0.118*
	ln(DEN)	0.053	0.106	-0.050	-0.046
		0.028	*0.034*	*0.068*	*0.088*
	ln(HK)	0.730	0.755	1.140	1.040
		0.153	*0.151*	*0.271*	*0.307*
	ln(JDIST)	-0.022	-0.166	0.354	-0.093
		0.027	*0.012*	*0.045*	*0.028*
	DR1:W.Eu.	-0.376		-0.943	
		0.166		*0.254*	
	DR2:C.Am.	-0.105		-1.423	
		0.350		*0.568*	
	DR3:S.Am.	-0.775		-3.167	
		0.229		*0.362*	
	DR4:M.E.	-0.935		-4.513	
		0.236		*0.518*	
	DR5:E.As.	1.774		4.102	
		0.295		*0.495*	
	DR6:S.As.	-0.185		-1.471	
		0.312		*0.565*	
	DR7:Afri.	-0.842		-2.855	
		0.249		*0.383*	
	DR8:Ocea.	0.525		2.075	
		0.180		*0.327*	

[NOTE] Time Dummies (DT1 - DT5) are included in all regressions.
The numbers in italics below the estimates are Eicker-White standard errors.
Z' = { C : Constant , POP : Population , YPC : per capita GNP , DEN : Density
HK : Human Capital, JDIST : Distance from Japan, DR1 - DR8 : Region Dummies}

TABLE2
U. S. : TRADE AND INVESTMENT EQUATIONS
ln (a + V) = max [Z'b + u , ln a]

Maximum Likelihood, Tobit Estimates

	V	Export	Export	DFI out	DFI out
	Observation #	456	456	456	456
	Log likelihood	-3333.44	-3461.19	-3341.37	-3418.73
	a	3.648	0.947	8.176	8.438
		0.782	*0.434*	*1.661*	*2.057*
	C	-0.819	-23.623	13.116	4.862
		3.631	*4.599*	*6.239*	*6.569*
	ln(POP)	0.746	0.778	0.927	0.828
		0.027	*0.033*	*0.055*	*0.054*
	ln(YPC)	-0.944	3.537	-5.022	-3.285
		0.808	*1.023*	*1.405*	*1.457*
	(ln(YPC))^2	0.120	-0.118	0.339	0.251
		0.045	*0.056*	*0.078*	*0.079*
	ln(DEN)	0.087	0.138	0.108	0.055
		0.029	*0.036*	*0.053*	*0.050*
	ln(HK)	0.378	0.395	1.368	1.428
		0.118	*0.141*	*0.281*	*0.288*
	ln(UDIST)	-0.129	-0.069	-0.055	-0.055
		0.016	*0.014*	*0.031*	*0.020*
Z	DR1:W.Eu.	-1.305		-0.974	
		0.180		*0.319*	
	DR2:C.Am.	-0.632		0.002	
		0.198		*0.414*	
	DR3:S.Am.	-1.102		-0.546	
		0.169		*0.332*	
	DR4:M.E.	-0.995		-2.909	
		0.356		*0.666*	
	DR5:E.As.	0.528		0.022	
		0.255		*0.507*	
	DR6:S.As.	-1.241		-2.890	
		0.274		*0.550*	
	DR7:Afri.	-1.319		-1.222	
		0.210		*0.508*	
	DR8:Ocea.	0.109		0.904	
		0.269		*0.540*	
	DR10:JPN	0.123		-1.003	
		0.209		*0.378*	

[NOTE] Time Dummies (DT1 - DT5) are included in all regressions.
The numbers in italics below the estimates are Eicker-White standard errors.
Z' = { C : Constant , POP : Population , YPC : per capita GNP , DEN : Density
HK : Human Capital , UDIST : Distance from US , DR1 - DR8, DR10 : Region Dummies}

TABLE 3
TRADE AND INVESTMENT ELASTICITIES

	With Region Dummies		Without Region Dummies	
Japan				
	JEXP	JOUT	JEXP	JOUT
Population	0.715	0.837	0.699	0.780
Income per Worker	1.085	0.583	1.056	0.854
Density	0.053	-0.050	0.106	-0.046
Human Capital	0.729	1.141	0.754	1.041
Distance from Japan	-0.022	0.354	-0.166	-0.093
U. S.				
	UEXP	UOUT	UEXP	UOUT
Population	0.747	0.929	0.778	0.830
Income per Worker	1.225	1.110	1.397	1.259
Density	0.087	0.108	0.138	0.055
Human Capital	0.378	1.371	0.395	1.432
Distance from U. S.	-0.130	-0.055	-0.069	-0.055

TABLE A1
REGION DEFINITIONS AND SAMPLES

North America

United States	(Japan)	Mexico	(Japan, U.S.)
Canada	(Japan, U.S.)		

Western Europe

United Kingdom	(Japan, U.S.)	Sweden	(Japan, U.S.)
Austria	(Japan, U.S.)	Finland	(Japan, U.S.)
Belgium-Luxembourg	(Japan, U.S.)	Greece	(Japan, U.S.)
Denmark	(Japan, U.S.)	Iceland	(Japan, U.S.)
France	(Japan, U.S.)	Ireland	(Japan, U.S.)
Germany	(Japan, U.S.)	Portugal	(Japan, U.S.)
Italy	(Japan, U.S.)	Spain	(Japan, U.S.)
Netherlands	(Japan, U.S.)	Turkey	(Japan, U.S.)
Norway	(Japan, U.S.)		

Central America

Costa Rica	(Japan, U.S.)	Honduras	(Japan, U.S.)
Dominican Republic	(U. S.)	Panama	(Japan, U.S.)
El Salvador	(Japan, U.S.)	Trinidad and Tobago	(Japan, U.S.)
Guatemala	(Japan, U.S.)		

South America

Argentina	(Japan, U.S.)	Paraguay	(Japan, U.S.)
Bolivia	(Japan, U.S.)	Peru	(Japan, U.S.)
Brazil	(Japan, U.S.)	Uruguay	(Japan, U.S.)
Chile	(Japan, U.S.)	Venezuela	(Japan, U.S.)
Colombia	(Japan, U.S.)	Guyana	(Japan, U.S.)
Ecuador	(Japan, U.S.)		

Middle East

Israel	(Japan, U.S.)	Syria	(Japan, U.S.)
Jordan	(Japan, U.S.)	Egypt	(Japan, U.S.)

East Asia

Taiwan	(Japan, U.S.)	Malaysia	(Japan, U.S.)
Hong Kong	(Japan, U.S.)	Philippines	(Japan, U.S.)
Indonesia	(Japan, U.S.)	Singapore	(Japan, U.S.)
Korea	(Japan, U.S.)	Thailand	(Japan, U.S.)

South Asia

Bangladesh	(Japan, U.S.)	Pakistan	(Japan, U.S.)
India	(Japan, U.S.)		

TABLE A1
REGION DEFINITIONS AND SAMPLES

Africa

Algeria	(U. S.)	Morocco	(Japan, U.S.)
Burundi	(U. S.)	Mozambique	(Japan, U.S.)
Cameroon	(Japan, U.S.)	Nigeria	(Japan, U.S.)
Central African Rep.	(U. S.)	Zimbabwe	(U. S.)
Gabon	(Japan, U.S.)	Rwanda	(Japan, U.S.)
Gambia, The	(Japan)	Senegal	(Japan, U.S.)
Cote d'Ivoire	(Japan, U.S.)	Sierra Leone	(U. S.)
Kenya	(Japan, U.S.)	Sudan	(Japan, U.S.)
Madagascar	(Japan, U.S.)	Tunisia	(Japan, U.S.)
Malawi	(U. S.)	Burkina Faso	(Japan)
Mauritania	(Japan)	Zambia	(Japan, U.S.)
Mauritius	(U. S.)		

Oceania

Australia	(Japan, U.S.)	Fiji	(Japan)
New Zealand	(Japan, U.S.)	Papua New Guinea	(Japan, U.S.)

Japan

Japan	(U. S.)

TABLE A2
DISTANCE DATA IN THE SAMPLE

DISTJ : Distances From Japan (TOKYO) in Km
DISTU : Distances From United States (Chicago) in Km

Country	City	SH C#	IFS C#	DISTJ	DISTU
U.S.A.	Chicago	71	111	10140	0
U.K.	London	140	112	9562	6378
AUSTRIA	Vienna	115	122	9131	7553
BELGIUM	Brussels	116	126	9456	6678
DENMARK	Copenhagen	120	128	8696	6855
FRANCE	Paris	122	132	9717	6677
GERMANY, WEST	West Berlin	123	134	8933	7098
ITALY	Rome	128	136	9864	7770
NETHERLANDS	Amsterdam	131	138	9292	6624
NORWAY	Oslo	132	142	8664	6685
SWEDEN	Stockholm	137	144	8173	6895
CANADA	Ottawa	54	156	10333	1049
JAPAN	Tokyo	94	158	0	10140
FINLAND	Helsinki	121	172	7824	7143
GREECE	Athens	124	174	9515	8761
ICELAND	Reykjavik	126	176	8800	4769
IRELAND	Dublin	127	178	9591	5899
PORTUGAL	Lisbon	134	182	11150	6438
SPAIN	Madrid	136	184	10768	6742
TURKEY	Ankara	139	186	8768	9137
AUSTRALIA	Canberra	143	193	7955	15106
NEW ZEALAND	Wellington	145	196	9275	13440
ARGENTINA	Buenos Aires	72	213	18359	9003
BOLIVIA	La Paz	73	218	16533	6789
BRAZIL	Brasilia	74	223	17686	7602
CHILE	Santiago	75	228	17230	8547
COLOMBIA	Bogota	76	233	14306	4340
COSTA RICA	San Jose	55	238	13171	3560
DOMINICAN REP.	Santo Domingo	57	243	13233	3094
ECUADOR	Quito	77	248	14430	4754
EL SALVADOR	San Salvador	58	253	12493	3126
GUATEMALA	Guatemala City	60	258	12323	3033
HONDURAS	Tegucigalpa	62	268	12601	3081
MEXICO	Mexico City	64	273	11309	2705
PANAMA	Panama	66	283	13547	3707
PARAGUAY	Asuncion	79	288	18007	8083
PERU	Lima	80	293	15492	6091
URUGUAY	Montevideo	82	298	18570	9112
VENEZUELA	Caracas	83	299	14169	4028
GUYANA	Georgetown	78	336	12522	2568
TRINIDAD&TOBAGO	Port-of-Spain	70	369	14402	4302
ISRAEL	Jerusalem	93	436	9155	9972
JORDAN	Amman	95	439	9085	10001
SYRIA	Damascus	110	463	8956	9887
EGYPT	Cairo	14	469	9578	9899
BANGLADESH	Dacca	85	513	4897	12727
TAIWAN	Taipei	111	528	2105	11998
HONG KONG	Hong Kong	88	532	2886	12546

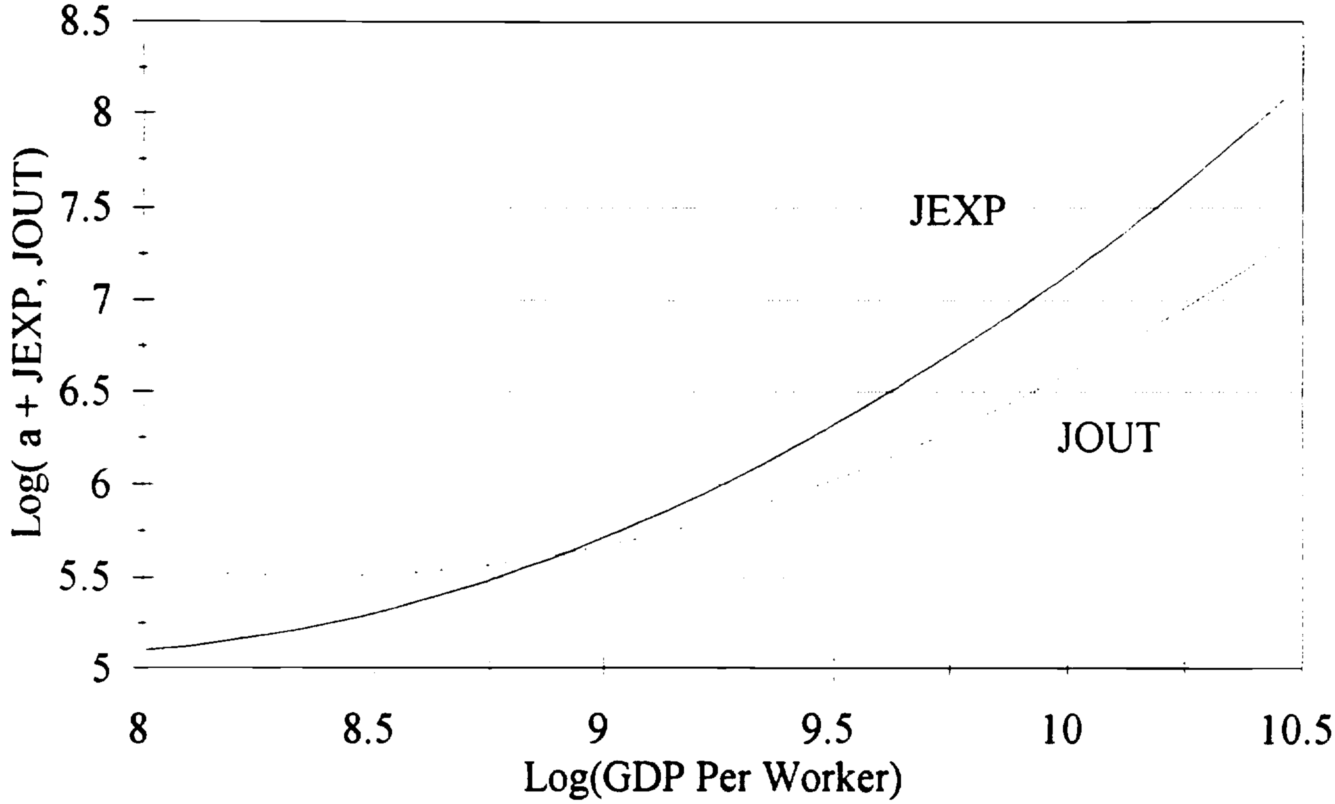
TABLE A2
DISTANCE DATA IN THE SAMPLE

DISTJ : Distances From Japan (TOKYO) in Km
DISTU : Distances From United States (Chicago) in Km

Country	City	SH C#	IFS C#	DISTJ	DISTU
INDIA	New Delhi	89	534	5848	12043
INDONESIA	Jakarta	90	536	5789	15807
KOREA, REP.	Seoul	96	542	1164	10525
MALAYSIA	Kuala Lumpur	99	548	5330	14938
PAKISTAN	Islamabad	104	564	5977	11404
PHILIPPINES	Manila	105	566	3007	13099
SINGAPORE	Singapore	108	576	5325	15089
THAILAND	Bangkok	112	578	4612	13788
ALGERIA	Algiers	1	612	10806	7454
BURUNDI	Bujumbura	6	618	12070	12480
CAMEROON	Yaounde	7	622	13071	10488
CENTRAL AFR.R.	Bangui	9	626	12461	11022
GABON	Libreville	16	646	13509	10577
GAMBIA	Banjul	17	648	14030	7463
IVORY COAST	Abidjan	21	662	14099	9097
KENYA	Nairobi	22	664	11262	12896
MADAGASCAR	Antananarivo	25	674	11416	15109
MALAWI	Lilongwe	26	676	12339	13643
MAURITANIA	Nouakchott	28	682	13498	7217
MAURITIUS	Port Louis	29	684	10639	15971
MOROCCO	Casablanca	30	686	11604	6853
MOZAMBIQUE	Maputo	31	688	13135	14358
NIGERIA	Lagos	34	694	13485	9628
ZIMBABWE	Harae	50	698	12813	13698
RWANDA	Kigali	36	714	11907	12427
SENEGAL	Dakar	37	722	13926	7300
SIERRA LEONE	Freetown	39	724	14337	8094
SUDAN	Khartoum	42	732	10486	11183
TUNISIA	Tunis	46	744	10425	7959
BURKINA FASO	Ouagadougou	5	748	13304	8788
ZAMBIA	Lusaka	49	754	12924	13296
FIJI	Suva	144	819	7240	11650
VANUATU	Port Vila	149	846	6660	12455
PAPUA N.GUINEA	Port Moresby	146	853	5083	13590

Figure 1

Japan Regression: Export and DFI out



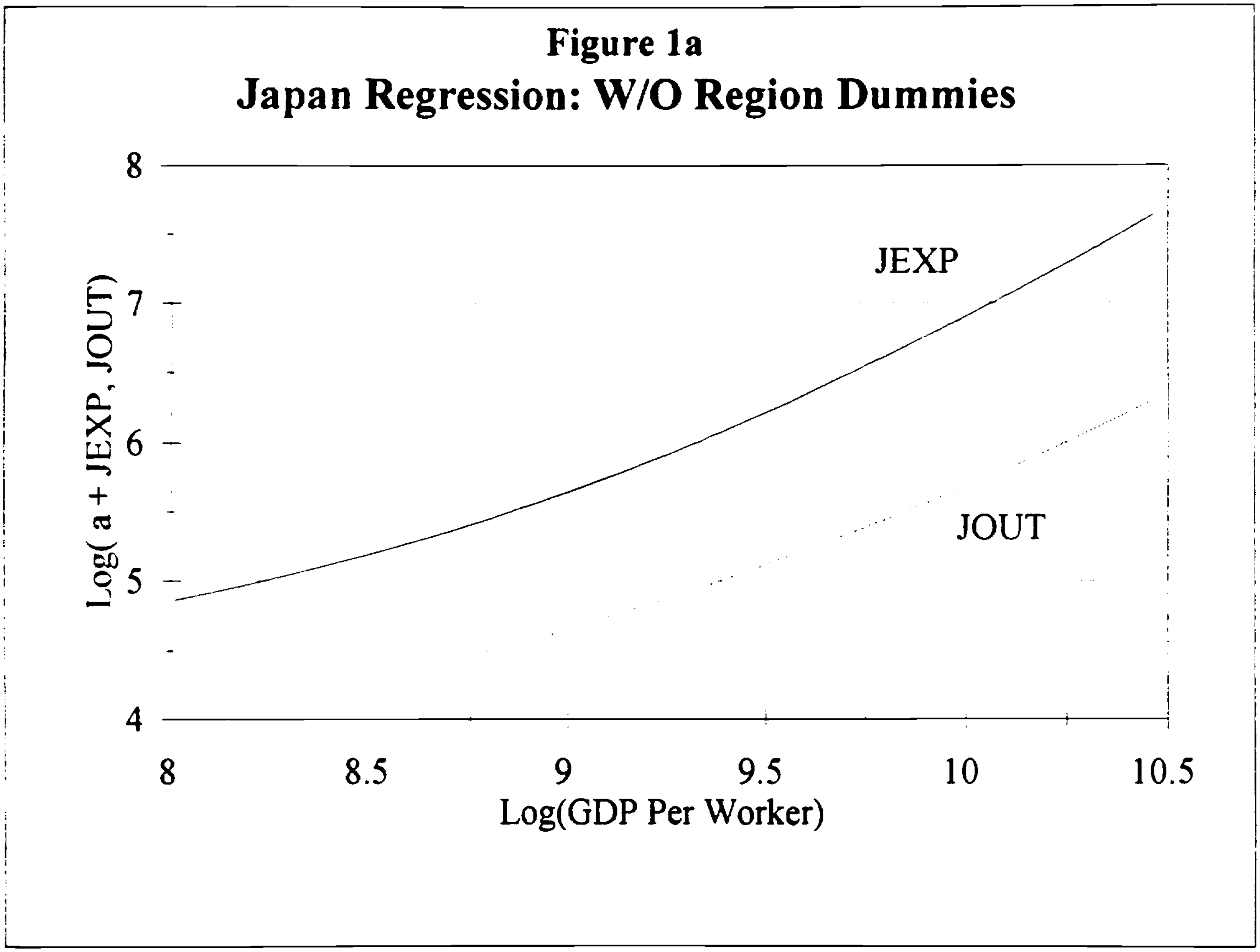


Figure 1a
Japan Regression: W/O Region Dummies
8
7
6
5
4
Log(a + JEXP, JOUT)
JEXP
JOUT
8
8.5
9
9.5
10
10.5
Log(GDP Per Worker)

Figure 2
U.S. Regression: Export and DFI out

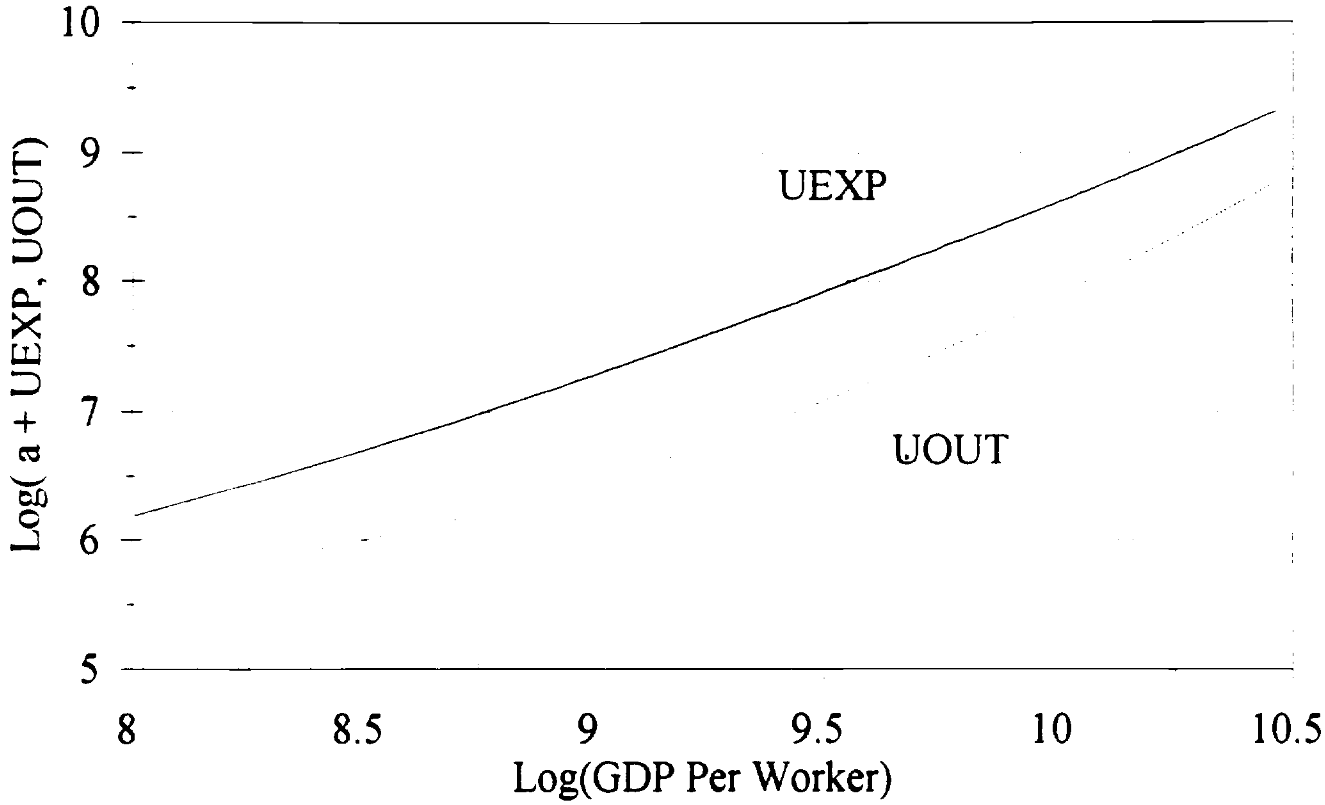


Figure 2a
U.S. Regression: W/O Region Dummies