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PRODUCTIVITY GROWTH AND CHANGES IN THE TERMS OF TRADE IN JAPAN AND THE U.S.

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ABSTRACT

In this paper we employ a recently proposed procedure (Diewert and Morrison [1985]) for adjusting real domestic product and productivity for changes in a country's terms of trade. We apply this procedure to a comparison of two major industrialized countries, the U.S. and Japan. The approach is based on assessing the impact on, alternatively, production or final sales to domestic purchasers, of changes in terms of trade and the balance of payments deficit in a consistent accounting framework. This treatment of international trade allows for comparative statics analysis based only on production theory. The comparison is carried out for a relatively open economy, Japan, with an economy that may not be as vulnerable to terms of trade changes, the U.S. for the years 1967 to 1982.

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Introduction

Changes in the terms of trade or the deficit have long been recognized to have a potential impact on production and productivity in an open economy. This impact has, however, proved difficult to measure precisely, particularly within the context of the theory of the producer which generally provides the basis for analysis of production and thus productivity.

Diewert and Morrison [1985] have recently proposed an index number method for measuring changes in production, input use, and terms of trade -- and thus ultimately productivity and "welfare" -- in response to changes in domestic and international input and output prices and technology. This development is based on production theory where the objective function is taken to be real product or sales, and the effect of changes in the terms of trade is analogous to technical change or total factor productivity change.

It is possible within this consistent accounting framework to assess the effects on domestic real output of changes in the terms of trade and the impact on final sales to domestic purchasers of changes in the balance of payments deficit. Combining these impacts results in a measure of welfare change including changes in both domestic productivity and in international economic conditions.

It is also possible to isolate the component indexes which are combined to compute the productivity and terms of trade indexes. The impact of changes in variables which are exogenous to the firm can be represented as individual price or quantity indexes within this structure, and thus the individual effects on the production process can be assessed.

In this paper we use the framework developed in Diewert and Morrison [1985] to consider the differential impact of terms of trade or deficit fluctuations on production and productivity in a relatively "closed" economy (the U.S.) as compared to a relatively "open" economy (Japan).

The paper proceeds as follows. In Section II we outline the fundamentals of the Diewert-Morrison [1985] approach to measurement of product price and input quantity indexes, productivity, terms of trade adjustment, and "welfare", and relate it to typical productivity measurement theory and techniques. In Section III we table our Japanese data for the years 1967-1982. In section IV, we present our productivity and terms of trade adjustment indexes for Japan. In section V, we table our U.S. data, while section VI presents our U.S. indexes. In section VII, we compare our Japanese and American results. Section VIII concludes.

II. The Treatment of Changes in Terms of Trade Within a Productivity Measurement Framework

Modeling the production process of firms within an open economy must take into account not only choices between different domestic inputs in producing domestic output, but also the choice between using imported inputs (commodity or merchandise imports) and/or producing export goods. More than one type of output must therefore be defined in order to capture the impact on the economy of the firm's production choices in response to changing domestic and foreign economic conditions. In this paper we recognize three classes of (net) output quantities: (i) sales to domestic purchasers (consumption goods, investment goods, and sales to the government sector), represented by the vector y_d with prices p_d and thus total value $p_d \cdot y_d = V_d$; (ii) sales to foreign purchasers (commodity or merchandise exports), y_x and p_x with value $y_x \cdot p_x = V_x$; and (iii) purchases of foreign inputs (commodity or merchandise imports), $-y_m$ and p_m with (negative) value $-y_m \cdot p_m = -V_m$. The impact of foreign trade, therefore, is represented by the extent of export production and import use by the production sector in addition to domestic production and input use. Note that we are assuming that all merchandise trade passes through the home country's private production sector.

Within this structure, the effect of changes in export or input prices can be assessed similarly to changes in total factor productivity. In analysis of production taking into consideration only domestic production and input use, it is standard to represent total factor productivity as the impact of a change in technology -- represented by an increase in a time counter t -- on production. This measure must, of course, adjust any total change in output for the accompanying changes in input use. The result of increased productivity from an improvement in technology (technical change) can be interpreted either as a potential decrease in input use required for a given production level, or an increase in output at a constant level of input use, given a constant price of output (production). A productivity improvement can therefore be thought of as an increase in "welfare" for the economy, since more output is potentially available using the same amount of input.

Similarly, if the price of an exported good increases, given the use of domestic inputs, then the same trade deficit can be maintained while consumption is increased; fewer resources may be devoted to producing exports or imports may be increased. In either case domestic production -- and thus welfare -- will increase. Thus a favorable change in the terms of trade (i.e., an increase in export prices relative to import prices) is similar to an increase in total factor productivity. In the remainder of this section we shall indicate how the independent impact of this international trade effect can be measured, using techniques that are analogous to traditional productivity measurement methods.

More specifically, changes in both domestic and international exogenous choice variables facing producing firms affect observed productivity measures.

The structure within which to analyze production and resulting productivity and "welfare" must therefore include these components of the total productivity "picture". We assume that the economy's period t private gross domestic product function or <u>product function</u> g^t may be defined for each period t as

$$1)\quad g^t(p,v) \equiv \max_y\{p\cdot y : (y,v)\varepsilon\Gamma^t\}$$

where $p = (p_x,p_m,p_d)^T >> 0_N$ is a (hypothetical) positive vector of net output prices that private producers face, $N=X+M+D$, p_x is a vector of X export prices, p_m a vector of M import prices, p_d a vector of D product prices, y is a corresponding vector of production quantities $y=(y_x,-y_m,y_d)$, and $v\geq 0$ is a non-negative vector of J primary inputs that are available to producers for each period t.

If g^t satisfies the usual regularity properties and producers are competively profit-maximizing, then by Hotellings's lemma the amounts of output produced and inputs used are derivable as $y_n = \partial g/\partial p_n$ for n a domestic or exported good, $-y_m=\partial g/\partial p_m$ for m an imported good, and $w_j = \partial g/\partial v_j$ for j=1,..., where w_j is the unit price of input j. Note that this is quite a general structure; in contrast to the usual framework, imports and exports are treated explicitly, and can be interpreted as inputs or outputs since they are net outputs. The product function g^t is the basis of the first approach to characterizing the impacts of terms of trade on productivity or welfare; the sales approach, within which the impacts of the deficit can also explicitly be assessed, will be outlined below.

Indexes such as productivity indexes and terms of trade indexes are based on aggregating the individual impacts of different price and quantity changes on the product function g. More specifically, the standard productivity definition is based on the domestic impact --- in terms of production or sales -- of a change in technology, given all exogenous variables constant. Formally, this can be expressed for the production approach by defining a standard theoretical productivity index as:

2) $R^t(p,v) \equiv g^t(p,v)/g^{t-1}(p,v)$.

R^t is therefore the percentage increase in output, given p and v, that can be produced by the period t technology set as compared to the period t-1 technology set.

To motivate the formulation of the productivity problem based on R^t and its extension to include terms of trade impacts it is useful to reformulate this definition of productivity for the moment in terms of more standard productivity literature and notation. To calculate the change in output R^t, or equivalently the growth rate ln R^t, it is necessary to isolate pure technical change from other observed changes in prices and quantities of inputs and outputs. In general in the productivity literature, therefore, productivity growth measurement is carried out by taking the total output change between two periods (the change in product value deflated by the change in output price) and dividing -- normalizing or deflating -- by the changes in individual input levels, to determine the increase in output produced for a given amount of input use. Thus if productivity is defined as the aggregate output (Q) to aggregate input (V) ratio (each aggregate being some kind of share-weighted sum), increases in productivity can be calculated as $(Q^t/V^t)/(Q^{t-1}/V^{t-1})$, or $(Q^t/Q^{t-1})/(V^t/V^{t-1})$. In proportional terms this is often written as (dlnQ/dt - dlnV/dt) or $\dot{Q}/Q-\dot{V}/V$. Note that the adjustment of the total change in Q accomplished by subtracting dlnV/dt accounts for only a portion of the total change based on g; the total change in g would also be a result of changes in the terms of trade.

The linkage between the R^t specification and typical productivity accounting methods can formally be motivated using the product function written to include explicitly the dependence on t. I.e., if $g=g(p,v,t)=g(p_x,p_m,p_y,v,t)$, then $\ln R^t(p,v)=\ln R(p,v,t)$ can be represented by $\partial \ln g/\partial t$, where:

$$3)\quad \frac{dg}{dt} = \Sigma_X \frac{\partial g}{\partial p_x}\frac{dp_x}{dt} + \Sigma_M \frac{\partial g}{\partial p_m}\frac{dp_m}{dt} + \Sigma_D \frac{\partial g}{\partial p_d}\frac{dp_d}{dt} + \Sigma_j \frac{\partial g}{\partial v_j}\frac{dv_j}{dt} + \frac{\partial g}{\partial t} \quad .$$

The independent impacts of productivity and terms of trade changes on the total change in product are therefore separately identifiable and interpretable. Characterization of productivity requires isolating the t impact, or

$$4)\quad \frac{\partial g}{\partial t} = \frac{dg}{dt} - \Sigma_X \frac{\partial g}{\partial p_x}\frac{dp_x}{dt} - \Sigma_M \frac{\partial g}{\partial p_m}\frac{dp_m}{dt} - \Sigma_D \frac{\partial g}{\partial p_d}\frac{dp_d}{dt} - \Sigma_j \frac{\partial g}{\partial v_j}\frac{dv_j}{dt} \quad ,$$

which, using Hotelling's lemma, dividing by g, and using ($\cdot$) to denote the time derivative, can be written as

$$5)\quad \ln R^t = \frac{\partial g}{\partial t}\cdot\frac{1}{g} = \frac{\dot{g}}{g} - \Sigma_X \frac{y_x p_x}{g}\frac{\dot{p}_x}{p_x} + \Sigma_M \frac{y_m p_m}{g}\frac{\dot{p}_m}{p_m} - \Sigma_D \frac{y_d p_d}{g}\frac{\dot{p}_d}{p_d} - \Sigma_j \frac{w_j v_j}{g}\frac{\dot{v}_j}{v_j} \quad ,$$

where terms 2, 3 and 4 on the right hand side of expression (5) are generally implicit in the construction of p_Q which deflates g to generate constant dollar product Q.

Note that if $g=p\cdot y=p_d\cdot y_d+p_x\cdot y_x-p_m\cdot y_m$ is interpreted as the value of the one product (or aggregated product) Q, $p_Q\cdot Q$, this expression is the basis for the usual $\dot{Q}/Q-\dot{V}/V$ categorization of productivity. In this case, $\dot{V}/V$ is the share-weighted index of the v_j inputs (the last term in (5)), the shares are in terms of Q, and the deflation of total product by all components of its price is explicit in the calculations.

In the expanded form for ln R^t given in (5) -- in contrast to the usual $\partial \ln Q/\partial t$ measure -- the dependence on productivity measurement of changes in p_x and p_m is explicitly included. The change in product R^t is thus purged of these effects and is a pure technical change measure.

Note that the right hand side of (5) allows us to independently assess the impacts of changes in productivity and in the terms of trade. The ln R^t measure can be augmented by a component based only on terms of trade changes, ln A^t to yield the following expression for ln W^t:

$$6)\ \ln R^t + \ln A^t = \frac{\partial g}{\partial t}\cdot\frac{1}{g} + \Sigma_X \frac{y_x p_x}{g}\,\frac{\dot{p}_x}{p_x} - \Sigma_M \frac{y_m p_m}{g}\,\frac{\dot{p}_m}{p_m} \equiv \ln W^t\ , \text{ or } W^t = A^t R^t\ ,$$

where international trade impacts are represented by A^t, and W^t captures productivity plus the effects on consumption of terms of trade changes. This indicator more closely reflects "welfare" than a typical productivity measure since increasing consumption is possible from increasing export prices relative to import prices.

Development of productivity and terms of trade indexes R^t and A^t and ultimately the combined "welfare" index W^t, requires development of all the component indexes of (3). These indexes can be interpreted as individual comparative statics indexes representing the separate impacts of changes in each of the components of the productivity expression -- and their individual elements -- on production.

Returning to a more formal treatment of the problem of computing productivity and welfare indexes including terms of trade effects, we define output and input price indexes between periods t-1 and t using the reference period r technology set (representing alternatively t or t-1).

First, to define a real product index (to capture the "Q's") it is necessary to define output price indexes to deflate the total change in value of output between periods t-1 and t. For each net output good n the individual output price effect in terms of the reference input vector v is defined as:

$$7)\quad P_n^r = g^r(p_1^{t-1},\ldots p_{n-1}^{t-1},p_n^t,p_{n+1}^{t-1},\ldots,p_N^{t-1},v)/g^r(p^{t-1},v)\quad .$$

which is equal to the proportionate increase in period r nominal product if the price of net output n were changed from period t-1 to period t prices but technology, other output prices and the primary input vector v were held constant at their period t-1 levels. Thus this number has a global comparative statics interpretation; (7) indicates the impact on production if only one output price (p_n) changed, <u>ceteris paribus</u>.

Diewert [1983] has shown that if g^r is defined as the following translog product function,

$$8)\quad \ln g^r(p,v) \equiv \alpha_0^t + \textstyle\sum_{n=1}^N \alpha_n^r \ln p_n + (1/2)\sum_{i=1}^N \sum_{j=1}^N \alpha_{ij}\ln p_i \ln p_j$$

$$+ \textstyle\sum_{m=1}^M \beta_m^r \ln v_m + (1/2)\sum_{i=1}^M \sum_{j=1}^M \beta_{ij}\ln v_i \ln v_j + \sum_{n=1}^M \sum_{m=1}^M \gamma_{nm}\ln p_n \ln v_m,$$

which is explicitly or implicitly often used as the basis for productivity analysis, and there is competitive profit-maximization behavior in each period, then certain indexes such as (7) can be calculated as translog indexes using observable data. More specifically, define the commodity n period t Laspeyres price effect, P^t_{Ln}, by (7) where $r\equiv t-1$ and $v\equiv v^{t-1}$ (so we are using the period t-1 input vector and the period t-1 technology as reference quantities) and define the commodity n period t Paasche price effect, P^t_{Pn}, by (7) where $r\equiv t$ and $v\equiv v^t$ (so the period t input vector and the period t technology are used as reference quantities). Then Diewert and Morrison [1985] show that the following global comparative statics result holds:

$$9)\quad (P_{Ln}^t\, P_{Pn}^t)^{1/2} = b_n \quad \text{, where}$$

$$\ln b_n \equiv (1/2)[(p_n^t y_n^t/p^t\cdot y^t) + (p_n^{t-1} y_n^{t-1}/p^{t-1}\cdot y^{t-1})]\ln(p_n^t/p_n^{t-1})\quad ,$$

Note that b_n may be empirically calculated.

Similar individual comparative statics effects can be defined for inputs. The input quantity effect for input j, $Q^t{}_j$, is defined as:

10) $Q^r_j = g^r(p, v_1^{t-1}, \ldots v_{j-1}^{t-1}, v_j^t, v_{j+1}^{t-1}, \ldots, v_J^{t-1})/g^r(p, v^{t-1})$.

This index represents the proportionate change in private product due to a change in the mth primary input between period t-1 and t, given fixed output prices, other primary inputs, and technology. Assuming that g^r is translog and there is competitive profit maximizing behavior, Diewert and Morrison [1985] show that

11) $(Q^t_{Lj} Q^t_{Pj})^{1/2} = c_j$, where,

$\ln c_j = (1/2)[(w_j^t v_j^t / w^t \cdot v^t) + (w_j^{t-1} v_j^{t-1} / w^{t-1} \cdot v^{t-1})] \ln(v_j^t / v_j^{t-1})$,

and where $Q_{Lj}{}^t$, the input j Laspeyres quantity effect, is defined by (10) for $r \equiv t-1$ and $p \equiv p^{t-1}$, and $Q_{Pj}{}^t$, the input j Paasche quantity effect, is defined by (10) for $r \equiv t$ and $p \equiv p^t$.

A theoretical period t aggregate output price index, using the input vector v and the period r technology set as reference quantities, may be defined by:

12) $P^r(p^{t-1}, p^t, v) \equiv g^r(p^t, v)/g^r(p^{t-1}, v)$.

Define $P^t{}_L$ by (12) where $r \equiv t-1$ and $v \equiv v^{t-1}$ and $P^t{}_P$ by (12) where $r \equiv t$ and $v \equiv v^t$. Then assuming (8) and maximizing behavior, Diewert and Morrison [1985] show that:

13) $(P^t_L P^t_P)^{1/2} = b \equiv P_0(p^{t-1}, p^t, y^{t-1}, y^t)$, where

$\ln b \equiv \sum_{n=1}^{N} (1/2)[(p_n^t y_n^t / p^t \cdot y^t) + (p_n^{t-1} y_n^{t-1} / p^{t-1} \cdot y^{t-1})] \ln(p_n^t / p_n^{t-1})$.

Note that $\Pi_{n=1}^{N}\ b_n = b$, so that the individual price effects can simply be combined to determine the aggregate price change for total product.

Since P_0 is empirically calculable this is an important result; this index can be used to deflate the total change in output value between period t-1 and t to derive the implied output quantity change index as:

$$14)\quad \tilde{Q}_0 = \tilde{Q}_0(p^{t-1},p^t,y^{t-1},y^t) \equiv p^t\cdot y^t/p^{t-1}\cdot y^{t-1}\ \ P_0(p^{t-1},p^t,y^{t-1},y^t)$$

$$\equiv a/b \text{ where a is defined as } p^t\cdot y^t/p^{t-1}\cdot y^{t-1}\ .$$

Thus, the real change in output dlnQ/dt between period t-1 and t -- the value change divided by the aggregate price change -- can be approximated by $\ln \tilde{Q}_0$.

The individual comparative statics effects in terms of input use can also be used to define the aggregate input quantity index dlnV/dt. The basis for this aggregate index is more formally defined as:

$$15)\quad Q^r(v^{t-1},v^t,p) \equiv g^r(p,v^t)/g^r(p,v^{t-1})\ .$$

Define $Q^t{}_L$ by (15) where $r \equiv t-1$ and $p \equiv p^{t-1}$ and $Q^t{}_P$ by (15) where $r \equiv t$ and $p \equiv p^t$. Then assuming (8) and maximizing behavior, it can be shown that:

$$16)\quad (Q_L^t Q_P^t)^{1/2} = c \equiv Q_0(w^{t-1},w^t,v^{t-1},v^t)\ ,$$

$$\ln c = \textstyle\sum_{j=1}^{M}(1/2)[(w_j^t v_j^t/w^t\cdot v^t) + (w_j^{t-1} v_j^{t-1}/w^{t-1}\cdot v^{t-1})]\ln(v_j^t/v_j^{t-1})\ ,$$

so that $\Pi_{j=1}^{J}\ c_j = c$. We can approximate dln V/dt by $\ln Q_0$.

Thus, in summary, the component comparative statics indexes, b_n and c_j can be combined to generate $\tilde{Q}_0$ and Q_0 which in turn can be used to compute the productivity measure $R^t \cong (R_L^t\ R_P^t)^{1/2} = \tilde{Q}_0/Q_0 = a/bc$, where R^t is defined as in (5), g is approximated by the translog function in (8), and the Paasche and Laspeyres indexes R_P^t and R_L^t are based on the reference price and quantity vectors (p^t,v^t) and (p^{t-1},p^{t-1}) in definition (2) respectively.[1]

The individual impacts of changes in the prices of internationally traded goods can be computed similarly to the comparative statics indexes above. In particular, the comparative statics impacts of p_x and p_m are structurally identical to the output price effects for the p_x and p_m components of the set of b_n indexes.

Theoretical indexes that capture the aggregate effects of changes in export and import prices respectively may be defined by

17) $P_x^r(p_d,p_x^t,p_m,p_x^{t-1},v) \equiv g^r(p_d,p_x^t,p_m,v)/g^r(p_d,p_x^{t-1},p_m,v)$ and

$P_m^r(p_d,p_x,p_m^t,p_m^{t-1},v) \equiv g^r(p_d,p_x,p_m^t,v)/g^r(p_d,p_x,p_m^{t-1},v)$

respectively. Define the Paasche export price and import price indexes, $P^t{}_{Px}$ and $P^t{}_{Pm}$, by using definitions (17) with $r\equiv t$ and all reference price and quantity vectors taken to be the period t observed vectors. Similarly, define the Laspeyres export and import price indexes, $P^t{}_{Lx}$ and $P^t{}_{Lm}$, by using (17) with $r\equiv t-1$ and all reference vectors set equal to their period t-1 levels. As usual, assuming that the translog form (8) holds and assuming maximizing behavior, we may derive the following equalities which express the aggregate impacts of changes in export and import price respectively:

18) $(P_{Lx}^t P_{Px}^t)^{1/2} = d$

where $\ln d = \sum_{i=1}^{X}(1/2)[(p_{xi}^t y_{xi}^t/p^t\cdot y^t) + (p_{xi}^{t-1} y_{xi}^{t-1}/p^{t-1}\cdot y^{t-1})]\ln(p_{xi}^t/p_{xi}^{t-1})$, and,

19) $(P_{Lm}^t P_{Pm}^t)^{1/2} = e$

where $\ln e = \sum_{i=1}^{M}(1/2)[(p_{mi}^t y_{mi}^t/p^t\cdot y^t) + (p_{mi}^{t-1} y_{mi}^{t-1}/p^{t-1}\cdot y^{t-1})]\ln(p_{mi}^t/p_{mi}^{t-1})$.

A theoretical index that captures the combined effects of changes in both export and import prices in period t may be defined by $A^r(p_d,p^t_x,p^t_m,p^{t-1}_x,p^{t-1}_m,v) \equiv g^r(p_d,p^t_x,p^t_m,v)/g^r(p_d,p^{t-1}_x,p^{t-1}_m,v)$. Define the usual Paasche and Laspeyres special cases of this family of indexes, A^t_P and A^t_L, by setting r equal to t or t-1 and taking reference price and quantity vectors to be period t or t-1 vectors respectively. Assuming (8) and maximizing behavior, we may compute the index A^t which represents the impact of all changes in the terms of trade by

$$20) \quad A^t \equiv (A^t_L A^t_P)^{1/2} = d/e,$$

where d and e are the indexes of the impacts of export and import price changes, on private product defined above by (5).

As outlined above (see (6)), the index A^t can be used as an adjustment index to add the impacts of terms of trade changes to technical change effects to obtain a "welfare" change index allowing for both domestic and international exogenous changes between periods t-1 and t. The welfare change measure W^t can be defined more formally by:

$$21) \quad W^t(p_d,v) \equiv g^t(p_d,p^t_x,p^t_m,v)/g^{t-1}(p_d,p^{t-1}_x,p^{t-1}_m,v) \quad .$$

Following the reasoning developed in Diewert and Morrison [1985] and the translog-based indexes developed above, for this function, as for R^t and A^t, a geometric mean of the Paasche and Laspeyres indexes W^t_P and W^t_L, can be calculated from observable data assuming maximizing behavior and the translog functional form (8). This implies in the current context that the geometric mean of W^t_P and W^t_L can simply be computed by combining the R^t and A^t indexes:

$$22) \quad (W^t_L W^t_P)^{1/2} = \left(\frac{a}{bc} \cdot \frac{d}{e} \right) = (R^t_L R^t_P)^{1/2} (A^t_L A^t_P)^{1/2} \equiv W^t \quad .$$

The entire development of productivity and "welfare" indexes including terms of trade changes to this point has been based on the product function. This is a useful framework that is analogous to the typical production function approach but expanded to include international price changes. This framework is not amenable, however, to consideration of the impacts of changes in the balance of trade deficit or surplus over time. This interesting addition to the current framework can be accomplished by using an alternative function as a basis for analysis, the private domestic sales function:

$$23)\quad s^t(p_d,p_x,p_m,v,v_0) = \max_{y_d,y_x,y_m}\{p_d\cdot y_d:\ (y_d,y_x,-y_m,v)\epsilon\Gamma^t;$$

$$p_x\cdot y_x - p_m\cdot y_m + v_0 \geq 0\} \quad .$$

This function is attractive because it depends on not only all the variable which are arguments of the product function, but also on the merchandise trade deficit v_0 -- the value of imports less the value of exports (if $v_0<0$, $-v_0$ is the trade surplus) -- that the private production sector is assumed to incur. The s^t function reveals how much domestic output the economy can produce in time t, given the availability of the vector of inputs v, the prices of exports and imports, p_x and p_m, and the ability to have a balance of trade deficit $v_0 \equiv p^t_m\cdot y^t_m - p^t_x\cdot y^t_x$. It may even more closely represent <u>short run</u> welfare changes than the product function since it directly captures the amount domestic purchasers receive.[2] Note, however, that the long run effect of a deficit will generally be opposite to the short run effect; i.e., current deficits may have to be paid back in the future.

Given the definition of v_0, profit maximizing behavior and constant returns to scale, it must be true that:

$$24)\quad s^t(p^t_d,p^t_x,p^t_m,v^t,v^t_0) = p^t_d\cdot y^t_d = p^t\cdot y^t + v^t_0 = w^t\cdot v^t + v^t_0 \quad .$$

The deficit v_0 functions in a similar way to a primary input: a bigger deficit (holding other things constant) will lead to a bigger equilibrium value of domestic sales. It therefore can explicitly be incorporated in a development of a "welfare" expression analogous to (6) but with s instead of g and an extra term depending on v_0, $-\partial s^t/\partial v_0^t \cdot dv_0^t/dt$, appended in the expression representing the total change in sales analogously to (3). Then, (5) becomes:

$$25)\ \ln R^{t*} = \frac{\partial s}{\partial t}\cdot\frac{1}{s} = \frac{\dot{s}}{s} - \Sigma_X \frac{y_x p_x}{s}\frac{\dot{p}_x}{p_x} + \Sigma_M \frac{y_m p_m}{s}\frac{\dot{p}_m}{p_m} - \Sigma_D \frac{y_d p_d}{s}\frac{\dot{p}_d}{p_d} - \Sigma_j \frac{w_j v_j}{s}\frac{\dot{v}_j}{v_j} - \frac{v_0}{s}\frac{\dot{v}_0}{v_0},$$

where the extra component of the total sales change indicates the new possible source of "welfare" change in addition to the previous productivity and terms of trade effects, the deficit effect.

More formally, in this framework the productivity index is defined analogously to the product function case but including v_0 and expressed in terms of domestic output. The productivity index $R^t(p,v)$ becomes $R^{t*}(p,v,v_0) \equiv s^t(p,v,v_0)/s^{t-1}(p,v,v_0)$. Following procedures elaborated above, we can use this definition to calculate a translog index of productivity between two periods t and t-1 (in which the deficit has the same sign) which is the geometric mean of the theoretical Paasche and Laspeyres productivity indexes:

$$26)\ (R_L^{t*} R_P^{t*})^{1/2} = a^*/b^* c_0^* c^* \equiv R^{t*}, \text{ where } a^* \equiv p_d^t \cdot y_d^t / p_d^{t-1} \cdot y_d^{t-1},$$

$$\ln b^* = \Sigma_{n=1}^{N} (1/2)[(p_n^t y_n^t / p_d^t \cdot y_d^t) + (p_n^{t-1} y_n^{t-1} / p_d^{t-1} \cdot y_d^{t-1})] \ln(p_n^t / p_n^{t-1})$$

$$\ln c_0^* = (1/2)[(v_0^t / p_d^t \cdot y_d^t) + (v_0^{t-1} / p_d^{t-1} \cdot y_d^{t-1})] \ln(v_0^t / v_0^{t-1}), \text{ and,}$$

$$\ln c^* = \Sigma_{j=1}^{J} (1/2)[(w_j^t v_j^t / p_d^t \cdot y_d^t) + (w_j^{t-1} v_j^{t-1} / p_d^{t-1} \cdot y_d^{t-1})] \ln(v_j^t / v_j^{t-1}) .$$

Clearly b* and c* are made up of components b_n* and c_j* exactly analogous to b_n and c_j above:

$$27)\quad (P_{Ln}^{t*}P_{Pn}^{t*})^{1/2} = b_n^* \quad , \text{ so } \quad \Pi_{n=1}^{N} b_n^* = b^* \quad , \text{ and,}$$

$$28)\quad (Q_{Lj}^{t*}Q_{Pj}^{t*})^{1/2} = c_j^* \quad , \text{ so } \quad \Pi_{j=1}^{M} c_j^* = c^* \quad .$$

In addition, in this case the deficit effect is c_0*, which is equal to:

$$29)\quad (Q_{L0}^{t*}Q_{P0}^{t*})^{1/2} = c_0^* \equiv Q_0^{t*} \quad .$$

(29) is thus a comparative statics index representing the proportionate change in private domestic sales from a change in the private sector's balance of trade deficit from v_0^{t-1} to v_0^t, with output, export and import prices, technology, and primary inputs constant. Note that when the deficit is equal to zero, $p_d \cdot y_d = w \cdot v$ for each period and c^*_0 will be equal to one so that the indexes from the product and sales approach will be identical. Thus, if the deficits are small in periods t and t-1, the indexes for the two approaches will be close.

A problem exists for implementation of these indexes, however, if v_0^t and v_0^{t-1} are of opposite signs, because ln c^*_0 is not defined in this case. As developed in Diewert and Morrison [1985], a first order approximation approach can be developed and used as an alternative when the deficit changes sign over the sample period. The basic idea of the approximation approach is as follows. Using the first derivatives of the sales function evaluated at the period t data point, the first order approximations to the theoretical Paasche and Laspeyres indexes can be computed and then used to form the geometric mean of the linear approximations. For example, for the index R^t, the approximation can be written as:

30) $\tilde{R}^t = (\tilde{R}^t_L \tilde{R}^t_P)^{1/2}$, where the approximation indexes $\tilde{R}^t_L, \tilde{R}^t_P$ are defined as

$$\tilde{R}^t_L \equiv [p^t_d \cdot y^t_d + y^t \cdot (p^{t-1} - p^t) + w^t \cdot (v^{t-1} - v^t) + (v_0^{t-1} - v_0^t)]/p_d^{t-1} \cdot y_d^{t-1} \quad ,$$

$$\tilde{R}^t_P \equiv p^t_d \cdot y^t_d/[p_d^{t-1} \cdot y_d^{t-1} + y^{t-1} \cdot (p^t - p^{t-1}) + w^{t-1} \cdot (v^t - v^{t-1}) + (v_0^t - v_0^{t-1})] \quad .$$

An analogous procedure can be carried out for any other index that is desired. This nonparametric approach, discussed in more detail in Diewert and Morrison [1985], will be used in section VII for purposes of comparison since, as we shall see in sections IV and VI, these indexes are nearly identical for those years in which no sign change in the deficit existed.

Terms of trade adjustment indexes can be defined for the sales approach analogously to the productivity indexes. Assuming that the sales function in each period is translog (where the quadratic coefficients are constant across time) and assuming maximizing behavior in all periods, we can show that a geometric mean of the Laspeyres and Paasche theoretical sales function terms of trade adjustment indexes is equal to an index number A^{t*} that can be evaluated empirically; i.e., we have

31) $(A^{t*}_L A^{t*}_P)^{1/2} = d^*/e^* \equiv A^{t*}$, where

$$\ln d^* = \textstyle\sum_{i=1}^{N_x} (1/2)[(p^t_{xi} y^t_{xi}/p^t_d \cdot y^t_d) + (p^{t-1}_{xi} y^{t-1}_{xi}/p^{t-1}_d \cdot y^{t-1}_d)]\ln(p^t_{xi}/p^{t-1}_{xi}) \quad \text{, and,}$$

$$\ln e^* = \textstyle\sum_{i=1}^{N_m} (1/2)[(p^t_{mi} y^t_{mi}/p^t_d \cdot y^t_d) + (p^{t-1}_{mi} y^{t-1}_{mi}/p^{t-1}_d \cdot y^{t-1}_d)]\ln(p^t_{mi}/p^{t-1}_{mi}) \quad .$$

Clearly these indexes are analogous to those developed for the product approach and pose no sign change difficulties. Again, if the deficit is zero the index d^*/e^* is identical to the product function adjustment index d/e in which the deficit is not taken into account. The interpretation also is analogous.

The R^{t*} and A^{t*} indexes capture the aggregate impact of changes in domestic and foreign exogenous variables, respectively, similarly to R^t and A^t with the product approach. These indexes can thus again be combined to determine the total impact of domestic and international fluctuations on productivity -- to derive "welfare" change indexes including the impact of terms of trade changes:

$$32)\quad (W_L^{t*} W_P^{t*})^{1/2} = (a^*/b^* c_0^* c^*)(d^*/e^*) = (R_L^{t*} R_P^{t*})^{1/2}(A_L^{t*} A_P^{t*})^{1/2} = R^{t*}A^{t*} = W^{t*} \quad .$$

Again, if c_0*=1 this index will be identical to W^t from (22). The W^{t*} index captures the combined comparative statics effect on private domestic sales of changes in export prices, import prices and technology, holding constant domestic output prices, primary inputs and the balance of trade deficit.

Using the sales approach, impacts from the balance of trade deficit can also be isolated and used to define an additional indicator of welfare. Since $p^t y^t + v_0{}^t = p_d{}^t y_d{}^t$, a bigger deficit increases the equilibrium value of domestic sales just like increasing production or a higher relative export price. These independent effects are explicitly identified in the sales function framework, and can thus be combined to obtain a combination "welfare" index augmented also by changes in the deficit.

In this context the concept of "welfare" includes the effects of increases in the deficit which cause "exogenous" increases in domestic sales and thus consumption similarly to a short run increase in total factor productivity. The deficit effect therefore becomes a third component of the welfare index that appends the changes in the deficit to the changes in total factor productivity and prices of exports and imports captured by the W^t and W^{t*} measures. Assuming (i) a translog sales function, (ii) that the balance of trade deficit has the same sign in periods t-1 and t, and (iii) maximizing behavior, we may derive the following equalities:

$$33)\ (T_L^{t*}T_P^{t*})^{1/2} = (a^*/b^*c_0^*c^*)(d^*/e^*)c_0^* \equiv T^{t*}$$

$$= (R_L^{t*}R_P^{t*})^{1/2}(A_L^{t*}A_P^{t*})^{1/2}(Q_{L0}^{t*}Q_{P0}^{t*})^{1/2}$$

$$= (W_L^{t*}W_P^{t*})^{1/2}(Q_{L0}^{t*}Q_{P0}^{t*})^{1/2} \quad .$$

Note that the development of the sales indexes as translog approximations has been based on the assumption that the productivity index R^{t*} is defined for all data points (i.e., we have implicitly assumed that the trade deficit has the same sign in all periods). The approximation given in (30) can be substituted for the R^{t*} index if this is not the case. It is also possible, in order to make the analysis more consistent, to carry out approximations to the other indexes which make up the welfare indexes. Unfortunately, the multiplicative properties of the indexes -- both in terms of the multiplication of the component "comparative statics" indexes into the productivity index and of the multiplication of the aggregate indexes to derive welfare measures -- do not carry through exactly if the first order approximation approach is used. This may not be a problem for empirical implementation since the indexes should be very closely comparable by the quadratic approximation lemma of Denny and Fuss [1983a][1983b]. This hypothesis will be assessed below for the available data points.

III. The Japanese Data

The Japanese data used for this study were developed from the Economic Statistics Annual from the Research and Statistics Department of the Bank of Japan. The data required are the prices and quantities of output (value added), labor, capital, exports and imports for each calendar year. The capital and labor series were generated from data on gross fixed capital formation, operating surplus, consumption of fixed capital, compensation of employees, and number of employees. Value added was then computed as the sum of the values of capital and labor. The export and import data, since they are the focus of this empirical illustration, were generated from more detailed value and "quantum" data for six different types of exports and seven imports. This will allow us to assess the impact of the energy price shock in the early 1970's.

More specifically, the data on capital was constructed by using a benchmark capital level (for 1966) supplied by John Helliwell and his associates at the University of British Columbia and based on OECD data, and then using the investment data from the Bank of Japan series on gross fixed capital formation along with a 12.5% rate of depreciation to construct the capital quantity series. The total value of capital ($w_K \cdot v_K = V_K$) was assumed to be the sum of the operating surplus plus the consumption of fixed capital. The price of capital was then computed as V_K/v_K. Bank of Japan series were also available for total compensation of employees ($w_L \cdot v_L = V_L$) and the number of employees (v_L), which were used to compute a price of labor as $w_L = V_L/v_L$.[3]

The export and import data, as mentioned above, included the value of six exports and eight imports plus totals. The export data encompassed separate information on food, textiles, chemicals, non-metallic minerals, metal and metal products, and machinery and equipment. The import data included food, textiles, metals, mineral fuels, other raw materials, chemicals, and machinery and equipment. The prices of each component were computed by dividing each value by the "quantum" indicator, which is described by the Bank of Japan as the total value divided by the unit value. The resulting prices were used to calculate aggregate prices for exports and imports by using a translog aggregation procedure. The resulting total values for exports and imports did not exactly coincide with the full totals due to a small miscellaneous component which was not provided with a quantum index. The quantities (or quantum values) were therefore re-generated by using the aggregated prices (p_x and p_m) along with the full total values of exports and imports (V_x and V_m) to compute the constant dollar quantity indexes y_x and y_m.[4]

Finally, value added ($p \cdot y$) was calculated as $V_y = V_L + V_K$ and the corresponding price (p) assumed to be equal to the implicit GDP deflator provided by the Bank of Japan. Absorption could then be calculated as $V_s = V_y - V_x + V_m$ and the price calculated implicitly as a translog index of the prices of these components of absorption. These data may be found in Table 1.

IV. Japanese Indexes of Productivity and "Welfare" Change and Their Components

The empirical results to be discussed in this section include (i) individual comparative statics price and quantity indexes b_n and c_j (and b^*_n, c^*_j) for Japan; (ii) combined indexes of different arguments of the product (and sales) functions a,b,c,d e ($a^*, b^*, c^*, c_0^*, d^*, e^*$) for Japan; and the combined productivity and welfare indexes for the translog product approach and the translog and nonparametric sales approaches $R^t, A^t, W^t, R^{*t}, A^{*t}, W^{*t}, T^{*t}, \tilde{R}^t, \tilde{A}^t, \tilde{W}^t$, and $\tilde{T}^t$. The indexes are presented as percentage changes and therefore vary around one; to see growth rates more clearly it is obviously straightforward simply to subtract 1.0 from all components of the indexes.

To begin the discussion of impacts on production from changes in input use, domestic prices and the terms of trade it is useful first to summarize the information available from the raw data. Many interesting trends emerge simply from consideration of the Japanese data (see Table 1). For example, over the relatively short time span considered -- the raw data are for 1966-82 -- the price of labor increased dramatically while the number of employees stayed relatively constant. Compensation per employee increased by at least a factor of seven during this time period while the number of employees increased by only 20%. By contrast, the data indicate that the capital rental price increased by approximately two times and the stock level by close to three times.[5] During the same time span output increased substantially; value added in constant dollars increased by a factor of almost three. The corresponding price of output also increased to approximately 275% of its value in the beginning of the sample.

The pattern of prices of traded goods is particularly interesting. The unit price of exported goods from Japan only doubled during this time period. The price of imported goods, however, provides a strong contrast to this. Although the price of some imported goods was actually falling slightly in the early 1970's, from 1972 to 1982 -- in response to dramatic increases in costs of raw materials and especially fuel -- the price of imported goods increased by a factor of four. Since these price trends are so different and international trade is fairly substantial in Japan, explicit consideration of terms of trade adjustments should have a relatively large impact on indexes for Japan. In addition, the balance of payments, $V_m - V_x$, is increasingly negative over this period; the value of exports becomes larger over time.

Information on single determinants of production trends is evident from the individual comparative statics indexes in Table 2. For example, c_L in Table 2 shows the impact on the change in product from increasing the use of labor. This index indicates that increases in the labor input have contributed to a greater product in all but two years -- 1974 and 1975 when labor growth actually reversed -- but the effect is negligible. By contrast, the contribution of increases in the capital stock represented by c_K is quite high; in 1970-74 in particular around 5% of product growth can be attributed to an increase in available capital. Similar trends for domestic sales are evident from c_L* and c_K*.

The impact of changes in prices are also provided by the individual comparative statics terms b_s, b_x, and b_m for the product approach and $b*_s$, $b*_x$, and $b*_m$ for the sales approach. b_s indicates the increase in the value of product attributable purely to domestic sales price increases. This index increased by a positive but decreasing proportion from about 7.7% in 1967 to .8% in 1982. The price effects $b*_s$, which indicate the increase in the value of domestic sales due to domestic sales price increases, follow an analogous pattern.

Looking at the effects b_x, the changes in the price of exports caused increased total value of product for most years. However, in some years -- 1968, 1971, 1972, 1976, 1977 and 1978 -- changes in the price of exports contributed to a very small decrease in product value. The $b*_x$ impacts are analogous.

The impacts of import price changes on product and sales, the b_m and $b*_m$, respectively, are particularly interesting. The substantial increase in import prices during the two energy crises leads to decreases in output for many years. This is particularly true for 1974, where the increase in the import price alone would have caused a 7% decrease in total product if not attenuated by changes in other determinants of the product level. Note, however, that later -- in 1977 and 1978 -- a slight increase in product could be attributed to import price changes; the aggregate price of imported goods actually declined in this period due partly to a drop in total fuels imported. The trends in b_m* are very similar to those for b_m.

The combined indexes a,b,c,d and e (a*,b*,c*,d*,e* and c_0*) are reported in Table 3. The a index is straightforward. It reveals the total percentage change in product (or, for a*, domestic sales -- both in terms of value) from the previous year. The b index shows the amount that can be attributed to the change in all components of the p vector; p_s, p_x, and p_m. It therefore combines all the b_n information from above. This index can be interpreted analogously to its component indexes. For example, the first energy price shock -- in terms of increases in p_m -- appears to have a large effect on the value of production, but the impact was delayed until 1975 instead of 1974 because b_a and b_x counterract the import component for 1974. The c index is similar; it shows that the combined effect on changes in product of capital and labor increases has been quite substantial. This is intuitively reasonable since input use is the major determinant of production growth. Finally, the d index represents only the impact of changes in the prices of exports; it is equal to b_x (and d* equal to b_x*). The import index, similarly, is the b_m ($b*_m$) index. The independent effect of the deficit for the translog sales approach is captured by the c_0* index. However, when the deficit changes sign, the $c*_0$ index is not defined. Thus for purposes of comparison, in Table 3 we also list the deficit index for the nonparametric sales approach, $\tilde{c}_0$. It can be seen that when $c*_0$ is defined, $\tilde{c}_0$ closely approximates $c*_0$. It can also be seen that these deficit effects can be quite large; for example, the 1973 increase in the balance of payments deficit over 1972 contributed to a 5.5% increase in domestic sales, holding all other factors constant.

Finally, these component indexes can be combined into productivity and welfare indicators for Japan. In Table 4 the productivity, terms of trade, and welfare indexes for the production, sales, and first order approximation approaches are presented. The productivity indexes R^t, R^{*t}, and $\tilde{R}^t$, which are computed as a/b•c for the product approach, a*/b*•c*•c_0* for the sales approach and approximate the latter expression for the first order approximation approach, are presented in the first column of Table 3. The indexes are all closely comparable which suggests that either R^t or $\tilde{R}^t$ are useful approximations to the R^{*t} data points which cannot be observed. All the indexes show a substantial decrease in productivity growth in the 1970-71 period and an even stronger impact in 1973-74 -- the rates of growth actually became negative. The post-1975 years were characterized by very healthy productivity rates although not quite as high as in the earlier years of the sample, particularly for 1981 which exhibited growth of only .2%. The largest percentage growth in the post energy crisis years was the "snap-back" in 1976 when growth jumped back up to 4.9%; this is closely followed by a 4.8% increase in 1980.

The adjustment indexes -- the A^t, A^{*t}, and $\tilde{A}^t$, indexes computed as d/e, d*/e* and an approximation to the latter term, respectively -- again are very closely related, and also are very close to one throughout the sample, with the exceptions of the OPEC price shock years of 1974 and 1979-80. The combined effect of changes in export and import prices in these years was a decrease in growth of over 3% in 1974, 1.5% in 1979 and almost 3% in 1980. Thus we are able to measure rather precisely the effects on growth of the adverse changes in Japan's terms of trade during these years.

Adjusting the productivity growth measures by these terms of trade indexes results in the welfare measures W^t, (R^tA^t), W^{*t} ($R^{*t}A^{*t}$) and $\tilde{W}^t$ ($\tilde{R}^t\tilde{A}^t$), which all are closely comparable and closely related to the "R" indexes since the A's are close to 1.0; The impacts of the energy "crisis" are, of course, more evident in these indexes; welfare growth in 1971 and particularly 1974 was very low.

Finally, for the sales and first order approximation approaches, the combined indexes incorporating productivity, terms of trade changes and the impact of the deficit are represented by T^{*t} ($W^{*t}c^{*}_{0}$) and $\tilde{T}^t$ (the corresponding approximation), respectively. These indexes are nearly identical for those years in which T^{*t} is defined. On average the productivity index $\tilde{R}^t$ and the total short run welfare change index $\tilde{W}^t$ differed by approximately 1%. The difference between the two series is of course due to the terms of trade adjustment index $\tilde{A}^t$ and the deficit adjustment index c^{*0t}; i.e., $\tilde{T}^t = \tilde{R}^t\tilde{A}^t\tilde{c}_0{}^t$. In section VII, we shall return to the Japanese series and compare them with the corresponding U.S. series.

V. The U.S. Data

The data required to calculate the indexes include price and quantity information on national output, capital and labor inputs, exports and imports. We have developed the output, import and export data for 1968-82 from the National Income and Product Accounts, (U.S. Department of Commerce [1981], [1982], [1983]), and have used real capital stock data constructed by the Bureau of Labor Statistics (U.S. Department of Labor [1983]) and real labor data updated from Jorgenson and Fraumeni [1981], since these series closely approximate our theoretically ideal indexes.

More specifically, we have calculated the value of output ($P_Y{}^t Y^t$) as gross domestic business product including tenant occupied housing output, property taxes, and Federal subsidies to businesses, but excluding Federal, State and Local indirect taxes and owner occupied housing. The corresponding price index ($P_Y{}^t$), was computed by cumulating the Business Gross Domestic Product Chain Price index. Note that our output series for the U.S. is conceptually somewhat different from our value added output series for Japan. The U.S. Y^t and $P_Y{}^t$ series may be found in Table 5.

The values of mercahndise exports ($p_x{}^t \cdot y_x{}^t$) and imports ($p_m{}^t \cdot y_m{}^t$) were determined by adding the durable and nondurable export and import values, respectively, reported in the National Accounts. Tariff revenues were added to the value of imports. Corresponding prices ($P_X{}^t$ and $P_M{}^t$) were calculated as translog indexes of the components of each measure, and quantities (X^t and M^t) were determined implicitly. For 1967-82, value and price data for nine different types of exports and ten types of imports were available, which were used to compute chain price indexes.

Using the values of imports and exports, $P_M{}^t M^t = p_m{}^t \cdot y_m{}^t$ and $P_X{}^t X^t = p_x{}^t \cdot y_x{}^t$, tax adjusted gross domestic private business sales to domestic purchasers, or absorption, was calculated as $P_S{}^t S^t = P_Y{}^t Y^t - P_X{}^t X^t + P_M{}^t M^t$. The corresponding price ($P_S{}^t$) determined by cumulating the gross domestic purchases chain price index from the National Accounts, and the constant dollar quantity S^t was calculated by division.

For our labor quantity series L^t, we used the series constructed by D. Jorgenson and B. Fraumeni, which is conveniently tabled in the U.S. Department of Labor [1983;77]. Our total private labor compensation series, $P_L{}^t L^t$, was taken from the same publication. The price of labor, $P_L{}^t$, was determined by division.[6]

For our capital services quantity series K^t we used the private business sector (excluding government enterprises) constant dollar capital serivces input tabled in the U.S. Department of Labor [1983;77]. In order to ensure that the value of privately produced outputs equals the value of pirivately utilized inputs, we determined the price of capital services $P_K{}^t$ residually, i.e., $P_K{}^t \equiv (P_Y{}^t Y^t - P_L{}^t L^t)/K^t$. All of these U.S. series are presented in Table 5.

VI. U.S. Indexes of Productivity and "Welfare" Change and Their Components

The patterns in the data for the U.S. vary considerably from those seen for Japan. For example, the price of labor did not increase nearly as substantially as it did in Japan and the corresponding change in labor quantity is much higher. Compensation to labor therefore increased similarly to Japan, but for the U.S. this was a result of increased levels of labor input whereas for Japan the price adjustment was more important. The capital trends are more similar; the U.S. price of capital increased slightly more than for Japan and the quantity increased a bit less, but the magnitudes are closely comparable. The output trend is analogous to that for capital; the volume of output increased more in Japan and price increased less than for the U.S. The import and export price and quantity trends also follow expected patterns. Import prices increased substantially in the U.S., particularly post-1973, but not as much as for Japan, and the increase in quantity of imports is similar for the two countries. By contrast, export price increases are more substantial for the U.S. and the corresponding increase in exports is much lower than for Japan.

Specific growth effects for the U.S. are presented in Table 6. The labor impact is different than for Japan, as would be expected from the differing labor trends; increases in the labor input in the U.S. have contributed to greater product except in the worst recession years including 1970, 1975 and 1982. Overall the contribution is strongly positive (and more so than in Japan which can be seen by the means of the respective c_L indexes). The positive impact of the capital stock is, by contrast, always positive but fluctuates less and the overall impact is less than for Japan, as is also evident from the reported means. The individual price impacts are particularly interesting for the U.S.; although the export price effects b_x and b^*_x caused increased product value in the U.S. in every year except 1982, changes in the price of imports reflected by b_m and b^*_m caused decreased product value except in 1982. The overall impacts are, however, especially for the earlier years, very small in magnitude. By contrast, the increase in product value from domestic price increases is positive and quite large throughout; it does not show the declining effect over time that is found for Japan. Domestic and export prices remained relatively high over the time period in the U.S. as compared to Japan.

The combined components of the productivity indexes for each type of effect; a, the change in product quantity alone; b, the change from all components of the price vector; c, the change from the combined input effects; d and e, the impact of exports and imports respectively; and c_0, the deficit effect, are presented in Table 7. These combined indexes are interpreted analogously to the individual impacts. For example, the c index indicates that the impact of changes in input on production growth has been quite substantial and positive, as one would expect. The d and e indexes are simply the b_x and b_m indexes. Note finally that the deficit effect is generally very small for the U.S.

The productivity and "welfare" indexes for the U.S. presented in Table 8 are combinations of the individual component indexes from Tables 6 and 7.

The productivity growth measure from the product approach, R^t, and its corresponding measures from the sales and first order approximation approaches, R^{*t} and $\tilde{R}^t$, are presented in the first column in Table 8. Note that these multifactor productivity indexes are quite similar, and capture large drops in productivity in 1970, 1975, 1979-80 and especially 1982. 1975 and 1976 were poor productivity years -- there was a 2% decrease in productivity -- which caused concern in the late 1970's about the observed "productivity slowdown".

The late 1960's were also disappointing and 1977 appeared very strong in terms of productivity growth. In addition, 1980 exhibited a 2% productivity decline and 1982 was catastrophic with a 6% drop in productivity. These patterns suggest that productivity trends cannot be characterized by a unique productivity downturn in 1973, although there does appear to be a trend toward deterioration of productivity growth over time, much of which can be attributed to output fluctuations represented by a/b.

To incorporate the effects on U.S. "welfare" of changes in the terms of trade in addition to changes in technical efficiency, the adjustment index $A_t = d/e$ and the corresponding indexes for the sales and first order approximations approaches, A^{*t} and $\tilde{A}^t$ must be calculated. These indexes are generally very close to 1.0, since internationally traded goods are such a small proportion of total output for the U.S., even in the most recent years of the sample. However, in 1974 and 1980 (two energy shock years), increases in the prices of imported goods relative to exported goods were responsible for declines in real output of about 1 1/2% in each year.

With the exception of these two years, the "welfare" index W^t, obtained by multiplying R^t and A^t (and analogously W^{*t} and $\tilde{W}^t$ for the sales and first order approximation approaches) does not vary significantly from R^t; for a relatively closed economy like the U.S., improvements in the terms of trade have a relatively small effect on economic welfare defined in this manner.

With the sales approach we can also assess changes in the deficit. Incorporating the deficit effect into the definition of welfare results in $T^{t*}=W^{t*}\cdot c_0^*$ for the sales approach and similarly $\tilde{T}^t$ for the first order approximation approach. The impact of multiplying by c_0^* was small, as one would expect from considering the deviations of c_0^* from one in Table 7. The exception to this is 1977, where the increase in the trade deficit relative to 1976 was large enough to account for an approximate 1.6% gain in real output.

VII. A Comparison of Japanese and U.S. Results for Productivity and "Welfare"

Although the indexes discussed above are illuminating individually, they are particularly interesting to compare across countries. For ease of comparison, in Table 9, productivity, terms of trade and welfare indexes for the product and first order approximation approaches are presented for both Japan and the U.S. for 1968-82. The indexes based on the product approach are presented because of the strong theoretical foundation for the translog treatment developed in Diewert and Morrison [1985] and outlined above. The first order approximation indexes are reported for comparison because the deficit effect can be captured within this framework and yet all the components of the indexes can be identified.

The first indexes to consider are those for productivity, R^t. The Japanese indexes show only two years of decline throughout the sample period, 1971 and 1974, whereas the U.S. indexes show declines in productivity in many years, including 1969-70, 1975-76, and 1979-82. This is a large portion of a sample that includes only 15 data points. The growth in productivity over the entire sample period for Japan was large relative to the U.S., and showed a gradual decline from around 6 to 3 percent per year, although there is a lot of fluctuation around the trend. The worst years for Japan were worse than the worst years for the U.S., but those years were very limited. Over all, both countries experienced a decreasing trend in yearly productivity growth over the sample period, but the U.S. decline was more pronounced, and the average level was substantially lower.

The U.S. pattern of productivity is different not only in levels but also in terms of timing and directions of change. For example, although for Japan

1974 was a disastrous year, with a productivity decline of more than 2.5%, there are indications of a snap back in productivity growth as early as 1975. For the U.S., 1975 and 1976 were both bad years with productivity declines of almost 2% per year.

The terms of trade adjustment indexes also are interesting to compare. Although the A^t indexes are close to 1.0 for Japan, they are even closer to 1.0 for the U.S. This is intuitively reasonable both because the magnitude of trade relative to GNP is large in Japan as compared to the U.S., and because the pattern of export prices as compared to import prices differs more for Japan than the U.S. This difference in price patterns at least partly results because Japan is more dependent on imported raw materials, especially fuels, than is the U.S. For example, the 1974 value of A^t for Japan, .969, is the lowest value over the sample period because of the impact of energy price increases. This value indicates a decrease in potential product of about 3% in response only to the change in the relative prices of traded goods. This corresponds to a U.S. value of .986 in 1974, the second lowest value in the sample, indicating a smaller 1.4% drop. On average the Japanese terms of trade adjustment values tend to be slightly lower than for the U.S. and lower than unity; the means are .995 and .977 respectively. This indicates a lower level of welfare overall than is suggested by the pure productivity measures R^t, due to changes in the terms of trade.

Adjustment of the productivity measures by the A^t indexes to derive the W^t indexes has little effect on the comparative welfare found for Japan and the U.S. The overall tendency is that the welfare indicators remain similar to the productivity indexes, although welfare growth is slightly lower than productivity growth, especially for the later years and for Japan.

For example, the 1982 numbers indicate both the worst productivity growth and the worst welfare growth for the U.S. during the sample period. Welfare growth is, however, slightly less disastrous; productivity dropped by 5.9% whereas welfare declined by 5.6%. Conversely, the best productivity growth year for the U.S., 1973, where productivity increased by approximately 2.9%, becomes slightly worse -- 2.8% -- when the terms of trade adjustment is made. By contrast, the worst productivity growth in Japan was found in 1974, where a 2.6% drop in productivity corresponded to a 5.6% decline in welfare. The terms of trade adjustment for Japan also transforms a strong increase in productivity growth of 4.8% to 1.9% in 1980 although at the beginning of the sample high productivity growth rates of more than 6% correspond to even higher welfare measures -- close to 7% in 1967. The terms of trade adjustment therefore has a more substantial impact on the relative welfare patterns in Japan than in the U.S.

The $\tilde{T}^t$ indexes including the adjustment for the deficit effect are also presented in Table 9. The pattern of this adjustment is similar to that of the adjustment to W^t from R^t. The U.S. numbers for the early 1980's indicate a less dramatic decrease in welfare growth toward the end of the sample with the deficit effect incorporated than was found for productivity growth, although the difference is negligible. By contrast, decreases in productivity earlier in the sample (such as -2.1% for 1970) appear slightly worse with the deficit transformation (-2.4%). The deficit adjustment for Japan also causes some of the earlier years to appear worse, for example the 1971 drop in welfare becomes greater than 4%. However, the effect on some later years is more negative and dramatic; welfare growth in 1981 actually appears negative and the welfare increase of 1.93% in 1980 is substantially worse than the 4.8% growth in productivity, although slightly larger than the 1.86% for W^t. On average the deficit effect causes welfare growth in Japan to appear worse than indicated by W^t, whereas the reverse is true for the U.S.

It is useful to focus on the last years of the sample both because this period was one of large fluctuations in growth of all industrial countries and because the major differences resulting from adjustments of productivity growth measurements to compute welfare growth appear in these years. The final comparison to be made here, therefore, is in terms of average growth rates to summarize the overall trends across time periods. These average growth rates for both Japan and the U.S. are presented in Table 10.

For the traditional productivity measures R^t and $\tilde{R}^t$ the difference between the 1968-82 percentage productivity growth average is striking; the U.S. experienced a decline overall in this period of approximately .1% per year, whereas Japan experienced an increase in productivity of a strong 3.0% per year. This discrepancy in productivity growth does not appear only after 1973, however. Although the pre-1973 average for the U.S. is a positive .8% growth, for Japan the corresponding rate of growth is almost 4%. The decline in productivity is, however -- at least on average -- a post-1973 effect. For the 1973-82 period the U.S. experienced a .35% decrease in productivity per year (although a .26% increase if 1982 is dropped) and the corresponding 2.6% growth experienced by Japan is lower than the pre-1973 rate of 4%, but still very high by international standards.

The trends in percentage growth captured in subperiods between the two OPEC shocks for the two countries also differs strongly. The 1973-77, and 1977-82 breakdown represents a first period including the first shock and beginning of the recovery and a second period including the rest of the recovery phase and second OPEC shock. This break corresponds to the end of the sample period for many studies studies from the late 1970's which assessed the devastating results of the energy price increases. These numbers pose some interesting questions.

For the U.S. the usual post-1973 productivity slowdown appears in modified form; the 1968-73 numbers are larger (.8%/year) than 1973-77 (.68%/year) although not by a large margin because of the bad productivity growth experienced in 1969-70. The 1977-82 numbers, however, are catastrophic; productivity decreased in this period by about .65%. Much of this decrease can be attributed, however, to 1982 since the 1977-81 percentage average growth is a positive .5%. This trend downwards, of course, hides the significant oscillations within the sub-periods; 1977 and 1978 were, for example, quite good years for productivity growth whereas 1970 was poor.

The Japanese averages indicate very different trends. First, the 1973-77 sub-period was a period of significantly lower annual productivity growth (2.1%) than 1968-73 (3.7%). The 1977-82 growth rate shows, however, a strong "snap-back" effect, even while including the second OPEC shock; the productivity growth rate jumps back up to 3.1%. The productivity growth trend for Japan, therefore, does not appear to be steadily downward as it does for the U.S., although the U.S. had a couple of good years in the late 1970's.

Adjustment by terms of trade effects -- to the W^t and $\tilde{W}^t$ measures -- and by deficit effects -- to the $\tilde{T}^t$ index -- change these patterns slightly but not dramatically. One point already noted about the Japanese productivity trends is that the post-1977 period appears weaker in terms of welfare as compared to the productivity trends, although for pre-1977 the adjustments have a much larger impact; welfare growth in the 1973-77 period is only 1.2% per year. The tendency toward a "welfare" slowdown and sluggish recovery in Japan is thus stronger than it appeared from the R^t indexes. This same tendency is evident in the U.S. indexes, but it is not as strong; welfare decreases appear greater than 1% per year for 1977-82 with the terms of trade adjustment (although when 1982 is dropped this becomes a decrease of .2%) and with the deficit adjustment the corresponding decrease is -.7% (+.16%), which is very close to the traditional productivity measure.

VIII. Concluding Remarks

Although the many theoretical and empirical results discussed in this paper cannot easily be summarized, it is useful to highlight some of these points to provide an overview of the contribution provided by this study.

First, it must be recognized that productivity measures, although important, may obscure significant contributions to short run welfare that are obtained by international trade. In this paper we have outlined, following a more rigorous treatment by Diewert and Morrison [1985], a method which can distinguish these additional "welfare" changes, resulting from changes in the terms of trade and the deficit, from productivity changes. To motivate and develop this approach we have used a production theory based framework similar to that which provides a basis for much of the productivity literature.

This framework is used to construct productivity, terms of trade adjustment and welfare indexes for the U.S. and Japan as combinations of individual comparative statics indexes representing the effects of output production, domestic output price, input use, the deficit, and export and import price changes on growth in production or sales.

These indexes show that Japan's productivity from 1968 to 1982 has been significantly greater than for the U.S. -- and in fact has been strongly positive in almost all years whereas productivity and welfare has been relatively low in the U.S. An interesting implication of these numbers is that Japan's productivity growth appears not to have been declining as significantly as the U.S.; Japan experienced a minimal number of very poor productivity growth years around the first OPEC energy price shock and then "snapped back" relatively quickly, although not completely. In addition, adjusting by the relative terms of trade faced, and the deficit incurred, by the countries has a greater impact for Japan than the U.S. and smaller productivity growth in post-1973 and especially 1973-77 than appears in productivity numbers. For the U.S. this is also true, although the effect is later; the most dramatic (negative) effects of the terms of trade adjustment are evident after 1977. Once the terms of trade and deficit effects are explicitly taken into account it appears for both countries for this time period that traditional productivity measures understate short run welfare.

These implications are obviously only a small subset of those which these indexes provide, but highlight the richness of the information available from the procedures developed. Application of these procedures to later and more complete data for these and other countries should provide very useful indications of the effects of trade patterns on economic welfare.

Japanese Quantities and Prices of K,L,Y,X,M, and S (Sales)

Table 1

YEAR	K	P_K	L	P_L	Y	P_Y
1967	29024.2	0.78710	41305.5	0.45343	54194.4	0.76405
1968	30654.1	0.87577	41994.0	0.52581	61100.4	0.80350
1969	33070.7	0.96136	42313.0	0.60483	68797.4	0.84201
1970	36316.2	1.03890	42766.3	0.73013	75335.9	0.90373
1971	40369.7	0.95311	42993.0	0.86284	78818.1	0.95054
1972	44320.0	1.00000	43035.0	1.00000	85815.0	1.00000
1973	48708.2	1.08639	44151.6	1.22489	93380.8	1.11940
1974	53883.1	1.08656	43966.9	1.55597	92531.9	1.34997
1975	57530.7	1.04612	43849.4	1.81640	95026.3	1.45533
1976	60671.8	1.10302	44252.4	2.04039	100089.4	1.54842
1977	63747.6	1.12564	44848.4	2.24906	104862.2	1.63615
1978	66957.2	1.21046	45402.5	2.39676	110281.2	1.71132
1979	70777.9	1.22444	45998.6	2.55838	115269.0	1.75614
1980	74882.9	1.25878	46477.1	2.75886	120847.1	1.80579
1981	78665.4	1.23931	46854.9	2.94883	125788/3	1.85284
1982	82516.0	1.25230	47333.5	3.12253	129723.4	1.88582

	X	P_X	M	P_M	S	P_S
1967	3940.108	0.96745	3836.849	0.95994	57191.9	0.72517
1968	4954.146	0.96083	4355.298	0.96187	62222.5	0.77682
1969	5882.085	0.99749	4992.975	0.96506	68738.2	0.82042
1970	6821.044	1.04710	5981.378	1.01768	76251.3	0.89196
1971	8266.639	1.03638	5989.071	1.07381	77216.8	0.95025
1972	8928.027	1.00000	6597.156	1.00000	85221.0	1.00000
1973	9512.114	1.09361	7953.468	1.18050	95460.4	1.12054
1974	11192.440	1.50515	7869.874	2.15937	95156.1	1.34471
1975	11278.783	1.55822	7040.110	2.43634	97603.6	1.43201
1976	13820.367	1.52077	7706.426	2.47283	103938.5	1.49972
1977	15047.310	1.50203	7920.279	2.40759	109137.5	1.55385
1978	15200.701	1.39419	8242.751	2.00481	117282.7	1.58858
1979	15027.924	1.57770	9095.688	2.61892	126517.7	1.63097
1980	17555.877	1.72185	8724.714	3.55662	132832.1	1.69111
1981	19466.441	1.80288	8275.875	3.79426	135839.3	1.71974
1982	18882.223	1.96821	8153.281	4.03833	143399.4	1.73282

Specific Growth Effects for Japan

Table 2

YEAR	b_s	b_x	b_m	c_L	c_K
1967	1.07684	1.00324	1.00083	1.00876	1.01915
1968	1.07067	0.99935	0.99982	1.00748	1.03046
1969	1.05527	1.00374	0.99972	1.00340	1.04273
1970	1.08580	1.00501	0.99544	1.00480	1.05290
1971	1.06391	0.99889	0.99536	1.00250	1.05748
1972	1.05092	0.99615	1.00575	1.00048	1.04859
1973	1.11896	1.00896	0.98651	1.01287	1.04843
1974	1.20088	1.03764	0.93356	0.99781	1.04943
1975	1.06517	1.00448	0.98465	0.99852	1.02963
1976	1.04707	0.99687	0.99819	1.00525	1.02302
1977	1.03561	0.99836	1.00310	1.00778	1.02102
1978	1.02194	0.99100	1.01825	1.00713	1.02091
1979	1.02657	1.01418	0.97312	1.00752	1.02389
1980	1.03724	1.01106	0.96138	1.00598	1.02419
1981	1.01693	1.00657	0.99123	1.00472	1.02085
1982	1.00753	1.01311	0.99179	1.00599	1.01991
Mean	1.06133	1.00554	0.98992	1.00506	1.03329

	b^*_s	b^*_x	b^*_m	c^*_L	c^*_K
1967	1.07762	1.00327	1.00084	1.00884	1.01934
1968	1.07123	0.99935	0.99982	1.00754	1.03068
1969	1.05612	1.00380	0.99972	1.00345	1.04338
1970	1.08720	1.00509	0.99536	1.00488	1.05375
1971	1.06535	0.99887	0.99526	1.00255	1.05876
1972	1.05236	0.99605	1.00590	1.00049	1.04996
1973	1.12054	1.00908	0.98636	1.01303	1.04907
1974	1.20005	1.03746	0.93389	0.99782	1.04925
1975	1.06492	1.00447	0.98471	0.99852	1.02952
1976	1.04729	0.99685	0.99818	1.00527	1.02312
1977	1.03609	0.99834	1.00314	1.00789	1.02130
1978	1.02235	0.99083	1.01859	1.00726	1.02130
1979	1.02669	1.01424	0.97306	1.00756	1.02401
1980	1.03687	1.01096	0.96174	1.00592	1.02395
1981	1.01693	1.00657	0.99123	1.00472	1.02084
1982	1.00761	1.01324	0.99171	1.00605	1.02011
Mean	1.06183	1.00553	0.98997	1.00511	1.03465

Components of the R^t (Productivity) and W^t (Welfare) Indexes for the Product and Sales Approaches, Japan

Table 3

YEAR	a	b	c	d	e	$\tilde{c}_0$
1967	1.18259	1.08122	1.02807	1.00324	1.00083	1.01438
1968	1.17687	1.06981	1.03816	0.99935	0.99982	0.98816
1969	1.17287	1.05892	1.04627	1.00374	0.99972	0.99172
1970	1.20160	1.08625	1.05795	1.00501	0.99544	1.00089
1971	1.09599	1.05780	1.06012	0.99889	0.99536	0.98152
1972	1.15590	1.05289	1.04909	0.99615	1.00575	1.00087
1973	1.22485	1.11377	1.06192	1.00896	0.98651	1.02469
1974	1.18656	1.16329	1.04714	1.03764	0.93356	1.00962
1975	1.10140	1.05353	1.02810	1.00448	0.98465	0.99170
1976	1.12431	1.04190	1.02838	0.99687	0.99819	0.99090
1977	1.09802	1.03712	1.02897	0.99836	1.00310	0.98906
1978	1.09989	1.03123	1.02819	0.99100	1.01825	0.99697
1979	1.07625	1.01314	1.03159	1.01418	0.97312	1.02983
1980	1.08877	1.00821	1.03031	1.01106	0.96138	1.00071
1981	1.05921	1.01463	1.02566	1.00657	0.99123	0.98131
1982	1.06568	1.01237	1.02602	1.01311	0.99179	0.99743
Mean	1.13192	1.05599	1.03849	1.00554	0.98992	0.99936

	a*	b*	c*	d*	e*	c^*_0
1967	1.20013	1.08205	1.02835	1.00327	1.00084	1.01774
1968	1.16545	1.07034	1.03845	0.99935	0.99982	0.98708
1969	1.16671	1.05983	1.04698	1.00380	0.99972	0.99233
1970	1.20603	1.08767	1.05889	1.00509	0.99536	1.00081
1971	1.07884	1.05909	1.06146	0.99887	0.99526	0.98160
1972	1.16144	1.05439	1.05048	0.99605	1.00590	1.00081
1973	1.25517	1.11529	1.06273	1.00908	0.98636	1.05548
1974	1.19623	1.16270	1.04696	1.03746	0.93389	
1975	1.09231	1.05332	1.02799	1.00447	0.98471	
1976	1.11526	1.04209	1.02851	0.99685	0.99818	0.98633
1977	1.08791	1.03762	1.02936	0.99834	1.00314	0.98915
1978	1.09865	1.03181	1.02872	0.99083	1.01859	0.99711
1979	1.10753	1.01325	1.03175	1.01424	0.97306	
1980	1.08862	1.00813	1.03001	1.01096	0.96174	1.00068
1981	1.03995	1.01463	1.02565	1.00657	0.99123	
1982	1.06368	1.01249	1.02627	1.01324	0.99171	0.99751
Mean	1.13274	1.05654	1.03891	1.00553	0.98997	1.00055

Table 4

Productivity, Terms of Trade Adjustment and Welfare Measures for the Product, Sales, and First Order Approximation Approaches, Japan

YEAR	R^t	A^t	W^t
1967	1.06389	1.00407	1.06821
1968	1.05963	0.99917	1.05875
1969	1.05862	1.00346	1.06229
1970	1.04560	1.00042	1.04604
1971	0.97735	0.99426	0.97174
1972	1.04646	1.00188	1.04842
1973	1.03561	0.99535	1.03080
1974	0.97408	0.96870	0.94359
1975	1.01687	0.98907	1.00575
1976	1.04931	0.99506	1.04413
1977	1.02892	1.00146	1.03042
1978	1.03734	1.00909	1.04677
1979	1.02976	0.98692	1.01629
1980	1.04814	0.97201	1.01880
1981	1.01781	0.99774	1.01551
1982	1.02596	1.00480	1.03089
Mean	1.03221	0.99522	1.02740

	R^{*t}	A^{*t}	W^{*t}	T^{*t}
1967	1.05974	1.00411	1.06410	1.08298
1968	1.06227	0.99917	1.06139	1.04768
1969	1.05958	1.00351	1.06331	1.05515
1970	1.04631	1.00043	1.04676	1.04761
1971	0.97765	0.99413	0.97192	0.95403
1972	1.04775	1.00193	1.04977	1.05063
1973	1.00333	0.99532	0.99863	1.05403
1974		0.96887		
1975		0.98911		
1976	1.05497	0.99504	1.04973	1.03538
1977	1.02974	1.00148	1.03126	1.02008
1978	1.03805	1.00925	1.04765	1.04463
1979		0.98691		
1980	1.04766	0.97228	1.01862	1.01931
1981		0.99774		
1982	1.02623	1.00484	1.03120	1.02863
Mean	1.03777	0.99526	1.03620	1.03668

Table 4 contd.

	$\tilde{R}^t$	$\tilde{A}^t$	$\tilde{W}^t$	$\tilde{T}^t$
1967	1.06432	1.00411	1.06872	1.08287
1968	1.06001	0.99917	1.05911	1.04753
1969	1.05941	1.00351	1.06316	1.05503
1970	1.04609	1.00044	1.04652	1.04737
1971	0.97693	0.99411	0.97116	0.95398
1972	1.04769	1.00192	1.04971	1.05056
1973	1.03541	0.99538	1.03046	1.05362
1974	0.97139	0.97052	0.94329	0.95176
1975	1.01699	0.98884	1.00576	0.99780
1976	1.04952	0.99504	1.04431	1.03534
1977	1.02930	1.00147	1.03082	1.02005
1978	1.03811	1.00917	1.04764	1.04461
1979	1.02966	0.98715	1.01632	1.04555
1980	1.04750	0.97225	1.01859	1.01929
1981	1.01782	0.99771	1.01551	0.99706
1982	1.02622	1.00485	1.03119	1.02863
Mean	1.03228	0.99535	1.02764	1.02694

U.S. Quantities and Prices of K,L,Y,X,M, and S (Sales)

Table 5

YEAR	K	P_K	L	P_L	Y	P_Y
1967	254.516	0.92252	543.092	0.72204	788.585	0.79501
1968	266.369	0.95383	556.789	0.77277	838.986	0.81567
1969	278.533	0.94054	576.440	0.82668	872.243	0.84667
1970	290.697	0.90078	570.485	0.88226	863.168	0.88646
1971	300.990	0.95611	573.463	0.93318	888.341	0.92636
1972	311.907	1.00000	595.496	1.00000	938.255	0.96712
1973	326.255	1.09631	625.866	1.06135	1021.939	1.00000
1974	340.914	1.08115	630.035	1.15423	1037.676	1.05601
1975	350.272	1.21930	611.574	1.22917	1019.453	1.15632
1976	356.822	1.32665	635.394	1.32006	1038.203	1.26385
1977	366.179	1.48218	666.360	1.40568	1086.373	1.33211
1978	379.279	1.57942	705.067	1.53092	1188.673	1.41203
1979	393.627	1.64533	736.629	1.66222	1229.876	1.52217
1980	407.663	1.70086	743.179	1.78329	1214.455	1.66221
1981	419.203	1.93726	759.257	1.93094	1257.408	1.81181
1982	435.110	1.86782	738.415	2.06104	1177.835	1.98212

	X	P_X	M	P_M	S	P_S
1967	36.0953	0.84947	35.6903	0.80249	779.516	0.80182
1968	38.9682	0.86270	43.2146	0.81339	830.649	0.82588
1969	40.8635	0.89104	45.5838	0.83500	860.247	0.86056
1970	45.2778	0.93788	47.4815	0.88906	846.679	0.90359
1971	44.6520	0.96959	51.5564	0.94030	869.694	0.95239
1972	49.3530	1.00000	58.6285	1.00000	916.821	1.00000
1973	61.2051	1.16592	62.7543	1.17375	981.204	1.04900
1974	65.9362	1.48958	60.7473	1.76037	996.297	1.10873
1975	63.9734	1.66677	53.1780	1.94587	960.740	1.22404
1976	66.5975	1.71765	65.1605	1.96222	994.593	1.33298
1977	66.9110	1.78929	72.8799	2.13216	1076.490	1.40762
1978	74.1455	1.90020	78.9832	2.29565	1146.755	1.49912
1979	82.6177	2.16876	80.0676	2.70617	1182.880	1.61455
1980	91.4960	2.40338	73.4325	3.41670	1160.537	1.76632
1981	88.0600	2.63230	74.0626	3.62441	1185.064	1.95356
1982	79.7703	2.62128	71.8893	3.53622	1116.955	2.12937

Specific Growth Effects for the U.S.

Table 6

YEAR	b_s	b_x	b_m	c_L	c_K
1968	1.02998	1.00076	0.99938	1.01574	1.01712
1969	1.04210	1.00159	0.99873	1.02234	1.01634
1970	1.05005	1.00269	0.99685	0.99326	1.01501
1971	1.05416	1.00180	0.99699	1.00341	1.01212
1972	1.05042	1.00165	0.99641	1.02494	1.01243
1973	1.04428	1.00967	0.98960	1.03303	1.01572
1974	1.06233	1.01974	0.96660	1.00437	1.01520
1975	1.10429	1.01017	0.99116	0.98083	1.00950
1976	1.08935	1.00267	0.99926	1.02470	1.00672
1977	1.05699	1.00344	0.99191	1.03074	1.00946
1978	1.06662	1.00497	0.99244	1.03669	1.01280
1979	1.07876	1.01195	0.98238	1.02881	1.01313
1980	1.09574	1.01056	0.97322	1.00581	1.01216
1981	1.10775	1.00962	0.99309	1.01401	1.00982
1982	1.09163	0.99959	1.00271	0.98213	1.01321
Mean	1.06830	1.00606	0.99138	1.01339	1.01272

	b^*_s	b^*_x	b^*_m	c^*_L	c^*_K
1968	1.03000	1.00076	0.99938	1.01575	1.01713
1969	1.04200	1.00159	0.99874	1.00286	1.01630
1970	1.05000	1.00269	0.99685	0.99327	1.01499
1971	1.05400	1.00179	0.99700	1.00340	1.01207
1972	1.05000	1.00164	0.99644	1.02473	1.01233
1973	1.04400	1.00962	0.98966	1.03281	1.01562
1974	1.06200	1.01963	0.96680	1.00435	1.01513
1975	1.10400	1.01015	0.99119	0.98089	1.00948
1976	1.08900	1.00266	0.99926	1.02460	1.00669
1977	1.05600	1.00338	0.99205	1.03021	1.00931
1978	1.06500	1.00485	0.99261	1.03581	1.01249
1979	1.07700	1.01169	0.98276	1.02818	1.01285
1980	1.09400	1.01038	0.97367	1.00571	1.01194
1981	1.10600	1.00947	0.99319	1.01379	1.00966
1982	1.09000	0.99960	1.00267	0.98243	1.01298
Mean	1.06753	1.00599	0.99148	1.01192	1.01260

Components of the R^t (Productivity) and W^t (Welfare) Indexes for the Product and Sales Approaches, U.S.

Table 7

YEAR	a	b	c	d	e	$\tilde{c}_0$
1968	1.09160	1.03013	1.03313	1.00076	0.99938	1.00567
1969	1.07913	1.04243	1.03905	1.00159	0.99873	1.00017
1970	1.03610	1.04955	1.00816	1.00269	0.99685	0.99742
1971	1.07553	1.05288	1.01556	1.00180	0.99699	1.00710
1972	1.10258	1.04838	1.03767	1.00165	0.99641	1.00496
1973	1.12620	1.04341	1.04926	1.00967	0.98960	0.99239
1974	1.07223	1.04712	1.01963	1.01974	0.96660	1.00627
1975	1.07595	1.10566	0.99016	1.01017	0.99116	0.98925
1976	1.11293	1.09145	1.03158	1.00267	0.99926	1.01414
1977	1.12750	1.05205	1.04049	1.00344	0.99191	1.01675
1978	1.13456	1.06381	1.04996	1.00497	0.99244	1.00312
1979	1.11534	1.07242	1.04232	1.01195	0.98238	0.99830
1980	1.07827	1.07766	1.01804	1.01056	0.97322	0.99660
1981	1.12857	1.11068	1.02397	1.00962	0.99309	1.00275
1982	1.02477	1.09415	0.99510	0.99959	1.00271	1.00297
Mean	1.09208	1.06545	1.02627	1.00606	0.99138	1.00252

	a*	b*	c*	d*	e*	c^*_0
1968	1.09756	1.03015	1.03315	1.00076	0.99938	
1969	1.07913	1.04234	1.03896	1.00159	0.99874	1.00017
1970	1.03344	1.04951	1.00816	1.00269	0.99685	
1971	1.08265	1.05272	1.01552	1.00179	0.99700	
1972	1.10690	1.04798	1.03736	1.00164	0.99644	1.00479
1973	1.11731	1.04314	1.04895	1.00962	0.98966	0.99141
1974	1.07834	1.04690	1.01953	1.01963	0.96680	1.00678
1975	1.06460	1.10537	0.99019	1.01015	0.99119	
1976	1.12737	1.09109	1.03146	1.00266	0.99926	
1977	1.14295	1.05115	1.03979	1.00338	0.99205	1.01655
1978	1.13452	1.06226	1.04875	1.00485	0.99261	1.00293
1979	1.11093	1.07080	1.04139	1.01169	0.98276	0.99838
1980	1.07334	1.07625	1.01772	1.01038	0.97367	0.99670
1981	1.12937	1.10888	1.02359	1.00947	0.99319	1.00259
1982	1.02735	1.09247	0.99519	0.99960	1.00267	1.00294
Mean	1.09372	1.06473	1.02598	1.00600	0.99148	1.00232

Table 8

Productivity, Terms of Trade Adjustment and Welfare Measures for the Product, Sales, and First Order Approximation Approaches, U.S.

YEAR	R^t	A^t	W^t
1968	1.02569	1.00014	1.02583
1969	0.99630	1.00032	0.99662
1970	0.97918	0.99953	0.97872
1971	1.00585	0.99879	1.00463
1972	1.01351	0.99806	1.01155
1973	1.02866	0.99917	1.02781
1974	1.00427	0.98568	0.98989
1975	0.98280	1.00124	0.98402
1976	0.98846	1.00193	0.99036
1977	1.03002	0.99532	1.02520
1978	1.01576	0.99737	1.01309
1979	0.99779	0.99412	0.99192
1980	0.98284	0.98350	0.96662
1981	0.99233	1.00264	0.99495
1982	0.94120	1.00231	0.94337
Mean	0.99900	0.99734	0.99631

	R^{*t}	A^{*t}	W^{*t}	T^{*t}
1968		1.00014		
1969	0.99631	1.00032	0.99663	0.99680
1970		0.99953		
1971		0.99879		
1972	1.01333	0.99807	1.01137	1.01622
1973	1.02996	0.99918	1.02912	1.02028
1974	1.00349	0.98578	0.98922	0.99593
1975		1.00124		
1976		1.00192		
1977	1.02870	0.99540	1.02397	1.04092
1978	1.01539	0.99743	1.01278	1.01575
1979	0.99785	0.99425	0.99211	0.99050
1980	0.98316	0.98378	0.96721	0.96403
1981	0.99244	1.00260	0.99503	0.99760
1982	0.94217	1.00227	0.94431	0.94708
Mean	1.00028	0.99738	0.99618	0.99851

Table 8 contd.

	$\tilde{R}^t$	$\tilde{A}^t$	$\tilde{W}^t$	$\tilde{T}^t$
1968	1.02572	1.00010	1.02582	1.03139
1969	0.99634	1.00024	0.99658	0.99675
1970	0.97941	0.99934	0.97876	0.97628
1971	1.00599	0.99861	1.00458	1.01147
1972	1.01354	0.99787	1.01137	1.01615
1973	1.02903	0.99852	1.02757	1.02018
1974	1.00404	0.98584	0.98991	0.99591
1975	0.98327	1.00079	0.98409	0.97388
1976	0.98833	1.00190	0.99019	1.00353
1977	1.02968	0.99512	1.02463	1.04085
1978	1.01552	0.99715	1.01260	1.01559
1979	0.99830	0.99358	0.99194	0.99033
1980	0.98403	0.98256	0.96713	0.96395
1981	0.99247	1.00239	0.99487	0.99746
1982	0.94218	1.00236	0.94438	0.94715
Mean	0.99919	0.99709	0.99630	0.99872

Productivity, Terms of Trade and Welfare Measures, Product and First Order Approximation Approaches, U.S. and Japan

Table 9

Japan

YEAR	R^t	$\tilde{R}^t$	A^t	$\tilde{A}^t$	W^t	$\tilde{W}^t$	$\tilde{T}^t$
1968	1.05963	1.06001	0.99917	0.99917	1.05875	1.05911	1.04753
1969	1.05862	1.05941	1.00346	1.00351	1.06229	1.06316	1.05503
1970	1.04560	1.04609	1.00042	1.00044	1.04604	1.04652	1.04737
1971	0.97735	0.97693	0.99426	0.99411	0.97174	0.97116	0.95398
1972	1.04646	1.04769	1.00188	1.00192	1.04842	1.04971	1.05056
1973	1.03561	1.03541	0.99535	0.99538	1.03080	1.03046	1.05362
1974	0.97408	0.97139	0.96870	0.97052	0.94359	0.94329	0.95176
1975	1.01687	1.01699	0.98907	0.98884	1.00575	1.00576	0.99780
1976	1.04931	1.04952	0.99506	0.99504	1.04413	1.04431	1.03534
1977	1.02892	1.02930	1.00146	1.00147	1.03042	1.03082	1.02005
1978	1.03734	1.03811	1.00909	1.00917	1.04677	1.04764	1.04461
1979	1.02976	1.02966	0.98692	0.98715	1.01629	1.01632	1.04555
1980	1.04814	1.04750	0.97201	0.97225	1.01880	1.01859	1.01929
1981	1.01781	1.01782	0.99774	0.99771	1.01551	1.01551	0.99706
1982	1.02596	1.02622	1.00480	1.00485	1.03089	1.03119	1.02863
Mean (1968-82)	1.03010	1.03014	0.99463	0.99477	1.02468	1.02490	1.02321

U.S.

	R^t	$\tilde{R}^t$	A^t	$\tilde{A}^t$	W^t	$\tilde{W}^t$	$\tilde{T}^t$
1968	1.02569	1.02572	1.00014	1.00010	1.02583	1.02582	1.03139
1969	0.99630	0.99634	1.00032	1.00024	0.99662	0.99658	0.99675
1970	0.97918	0.97941	0.99953	0.99934	0.97872	0.97876	0.97628
1971	1.00585	1.00599	0.99879	0.99861	1.00463	1.00458	1.01147
1972	1.01351	1.01354	0.99806	0.99787	1.01155	1.01137	1.01615
1973	1.02866	1.02903	0.99917	0.99852	1.02781	1.02757	1.02018
1974	1.00427	1.00404	0.98568	0.98584	0.98989	0.98991	0.99591
1975	0.98280	0.98327	1.00124	1.00079	0.98402	0.98409	0.97388
1976	0.98846	0.98833	1.00193	1.00190	0.99036	0.99019	1.00353
1977	1.03002	1.02968	0.99532	0.99512	1.02520	1.02463	1.04085
1978	1.01576	1.01552	0.99737	0.99715	1.01309	1.01260	1.01559
1979	0.99779	0.99830	0.99412	0.99358	0.99192	0.99194	0.99033
1980	0.98284	0.98403	0.98350	0.98256	0.96662	0.96713	0.96395
1981	0.99223	0.99247	1.00264	1.00239	0.99495	0.99487	0.99746
1982	0.94120	0.94218	1.00231	1.00236	0.94337	0.94438	0.94715
Mean	0.99899	0.99919	0.99734	0.99709	0.99631	0.99630	0.99872

Average Growth Rates for Productivity and Welfare, Selected Years Japan and the U.S.

Table 10

YEARS	R^t	$\tilde{R}^t$	W^t	$\tilde{W}^t$	$\tilde{T}^t$
Japan					
1968-82	.03010	.03014	.02468	.02490	.02321
1973-82	.02638	.02619	.01830	.01839	.01930
1968-73	.03721	.03759	.03634	.03669	.03468
1973-77	.02096	.02052	.01094	.01093	.01157
1977-82	.03132	.03144	.02645	.02668	.02586
U.S.					
1968-82	-.00101	-.00081	-.00369	-.00370	-.00128
1973-82	-.00359	-.00332	-.00728	-.00548	-.00512
1968-73	.00820	.00834	.00753	.00745	.00870
1973-77	.00684	.00687	.00346	.00328	.00687
1977-82	-.00667	-.00630	-.01081	-.01074	-.00744

Footnotes

[1] See Diewert and Morrison [1985] for further details.

[2] See Diewert and Morrison [1985] for further elaboration.

[3] Two other approximations were also tried for purposes of comparison. These included dividing the compensation of labor series by the "average month hours per worker" to generate a price of labor series and using "cash earnings per regular worker" to approximate a labor price. These two methods resulted in series which bounded the price of labor data used in the study.

[4] It appeared important, particularly for mineral fuels, to decompose these indexes to allow for the individual impacts of the different categories to appear; the fuel component of imports exhibited a dramatic jump in value and price in the 1974 data which is important to capture explicitly.

[5] This occurs even though the depreciation rate was assumed to be quite high -- 12.5% --. This assumption was made as a result of evidence that replacement investment is a significantly higher portion of total investment relative to the U.S. experience.

[6] The BLS labor quantity series is an unweighted manhours series and hence is unsuitable for our purposes. We wish to thank Mike Harper at BLS and Barbara Fraumeni for their help in providing the updated data series.

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