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A PARTIAL EXPLANATION OF JAPANESE ECONOMIC
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The Hitotsubashi Academy
Hitotsubashi University
Kunitachi, Tokyo
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REAL MONEY BALANCES AND PRODUCTION: A PARTIAL EXPLANATION OF JAPANESE ECONOMIC DEVELOPMENT FOR 1952-1968[†]

By ALLEN SINAI* AND HOUSTON H. STOKES**

I. Introduction

This paper examines the hypothesis that real money balances were a significant productive input in the postwar Japanese economy, hence an important source of changes in productivity. Scholars have had difficulty explaining recent Japanese economic growth in terms of conventional factor inputs and calculations of total factor productivity have been quite large.¹ If real balances were a factor of production in Japan,² then omitting them from the production function could be responsible for the sizable "residual" that has been found.³

To test the above notion, an unconstrained Cobb-Douglas (CD) production function was estimated for the Japanese economy from 1952-1968. The CD function was applied to a set of data developed by Kosobud [1974], who followed the methods of Christensen and Jorgenson [1970] in developing Divisia indices of outputs and inputs.⁴ The results indicate that real balances were a significant input in the aggregate production function. The contribution of real balances was found to be as a factor of production, rather than a source of technological change [Moroney, (1972, pp. 340-342)].

* Vice President and Senior Economist of Data Resources Inc.

** Associate Professor of Economics at the University of Illinois, Chicago Circle.

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¹ Ohkawa [1968] found that total factor productivity accounted for about one-half of the growth in output in Japan from 1955-1965. Yoshihara and Ratcliffe [1970] attributed one-third of the growth in Japanese output to total factor productivity. Kosobud [1974], using improved measures of outputs and inputs, determined that total factor productivity contributed 60.1% to the growth of output in Japan from 1952-1968.

² Recent literature in the area of monetary theory has dealt with the role of real balances in exchange, (Brunner and Meltzer [1971]). Some writers (Mundell [1971] and Bailey [1971]) emphasize the "direct" productivity of real balances, suggesting that real balances should be a third input in the aggregate production function. Others such as Classen [1975] discuss the "indirect" productivity of real balances in augmenting the productivity of labor and capital. Evidence concerning the role of real balances as a third factor of production has been presented for the U.S. by Sinai and Stokes [1972]. These findings are in conflict with the view that the role of real balances ends with the evolution of a barter economy to a monetary economy. (See Pierson [1972, p. 393].) Japan in the period 1952-1968 provides a particularly good opportunity to resolve the issue since in the above mentioned period of substantial growth, real balances increased 11.9% per annum, real output increased 11.6% per annum, while labor and the capital stock only increased at an annual rate of 1.05% and 9.73%, respectively.

³ A recent important study by McKinnon [1973, ch. 8] has identified banking-financial system growth, measured by the ratio of monetary liabilities to GNP, as a key factor in Japanese economic development since 1953. Thus real money balances is a likely proxy for development of the banking-financial system.

⁴ For a discussion of the properties of Divisia indices, see Richter [1966].

When a measure of technical change (time) was inserted in the CD production function specified with and without real balances, serious multicollinearity between the shift parameter (time) and some of the inputs precluded testing the relative contributions of real balances, disembodied technical change and other factor inputs. This problem was solved by regressing a measure of total factor productivity on the time trend, real cash balances and a measure of imported technology.⁵ Using this procedure, real money balances and the real value of imported technology were found to be the major determinants of shifts in the production function.

Section II presents the CD function used in the first part of this study, describes the data, and discusses the identification of the production function. Extensive tests for the possibility of reverse causation between money balances and output are performed to insure that the estimated regression does not reflect a spurious relation between real balances and income. The empirical findings of the CD production function model, together with the alternative specification used to measure the relative contribution of real balances, are treated in Section III. Section IV provides a summary and the conclusions.

II. Identifying a Production Function for the Japanese Economy

Although the best situation for observing the productivity of real balances may occur when a country is in transition from a barter to a monetary economy, the necessary data usually are lacking. Other instances well suited for measuring the role of real cash balances in production would be in a developing economy or one that is recovering from the ravages of war or a depression. In all of these cases rapid strides in the efficiency of internal exchange and foreign trade usually occur, with the result that large quantities of physical resources are released from use in exchange activities. The postwar situation in Japan makes that country an appropriate subject for the present study.⁶

A. Specification of the Production Function

The production function was specified as CD with non-constant returns to scale,⁷

⁵ Total factor productivity was calculated by Kosobud (1974), using a CD equation containing only labor and capital.

⁶ There is general agreement that Japan's economy suffered dislocations from W.W. II until the early 1950's. "Normal" postwar growth can be dated from that point. Subsequently, the very rapid economic progress in Japan took her economy to the ranks of the most industrialized countries in the world. Thus, the process of Japanese economic development during 1952-1968 appears to have spanned the spectrum of exchange efficiency.

⁷ A test suggested by Kmenta [1967, pp. 180-181] was performed to determine whether a CD or CES production function was appropriate for this study. The results supported the use of the CD functional form for estimating the production function. The Kmenta test also justified the assumption of non-constant returns to scale. Although the Kmenta test strictly applies to a two input production function, we have assumed the CD form determined in this way applicable to a production function with three inputs. There is no known way to discriminate between the CD and CES production functions when there are three inputs:

The results of the Kmenta test were

$$(2) \quad \ln Q = .0071 + 1.725 \ln L + 1.008 \ln(K/L) - .013 \ln(K/L)^2$$

(.022)	(.333)	(.087)	(.060)
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$\bar{R}^2 = .998$
 DW = 1.91
 SEE = .028
 Period of Fit 1952-1968

$$(1) \quad Q = Ae^{\lambda t} L^\alpha K^\beta m^\delta u$$

where Q =real output

L =labor services

K =capital services

m =real money balances

t =a variable representing unexplained shifts in the production function (time trend)

A =an efficiency parameter

λ =the rate of disembodied or neutral technological change

α =elasticity of output with respect to labor services

β =elasticity of output with respect to capital services

δ =elasticity of output with respect to real money balances

u =disturbance term.

The variable t was used to represent shifts in the production function over time. In the literature t is generally defined as a time trend and has been used as a proxy for disembodied technical change.

Equation (1) was estimated in log linear form as

$$(3) \quad \ln Q = \ln A + \alpha \ln L + \beta \ln K + \delta \ln m + \lambda t + u'$$

where $u' = \ln u$. The disturbance u was assumed to be log normally distributed with mean $\mu^{\sigma^2/2}$ and variance $u^{\sigma^2}(\sigma^2 - 1)$. Hence $E(u') = 0$, $E(u')^2 = \sigma^2$ and $E(u_i' u_j') = 0$, $i \neq j$. Ordinary least squares was employed to estimate equation (3). Problems of simultaneous equations bias and aggregation, although potentially substantial, were not dealt with at this time.⁸

B. The Data

Data for output, labor and capital services were taken from the study of Kosobud [1974]. He followed the methods of Christensen and Jorgenson and constructed Divisia quantity indices of gross enterprise national product, labor and capital services.⁹ For

where \bar{R}^2 is the adjusted coefficient of multiple determination, SEE is the standard error of estimate, and DW is the Durbin-Watson statistic. The coefficient of the last term in the regression was not statistically significant. It is equal to $-1/2 \rho \gamma \delta$ where ρ is a substitution parameter, γ a scale parameter, and δ a distribution coefficient. The coefficient of $\ln(K/L)$ was significant and is defined as $\gamma \delta$. Therefore, ρ equals zero and $\sigma = 1/(1 + \rho)$, the elasticity of substitution, is unity. The coefficient of $\ln L$ indicates increasing returns to scale of 1.725. In the subsequent empirical work we found increasing returns to scale (with and without real money balances in the production function) of at least the order of magnitude in the Kmenta approximation.

⁸ In principle a simultaneous equations model containing the production function and marginal productivity conditions for the inputs could be specified. Unfortunately, the assumptions necessary to deal with a three factor case, where one factor is real money balances, are not entirely clear.

⁹ There were some minor differences between the Christensen-Jorgenson and Kosobud approaches to the data. These were due primarily to a lack of adequate data. For example, excise and sales taxes were not subtracted from output in Kosobud's study. Kosobud included indirect business taxes as part of factor outlays. He did not add production subsidies to output but included as part of output government expenditures on transportation power and communication. There was not as detailed a disaggregation of capital as in Christensen-Jorgenson. Some of the estimates, e.g., of rental prices and wages, required uncertain statistics. However, Kosobud appears to have followed Christensen-Jorgenson as closely as possible and his data are probably superior to any other for the postwar Japanese economy.

As one test for the quality of Kosobud's data, all regressions in this study were reestimated with a set of conventional measures taken from the Japanese income and product accounts. Substantial differences were exhibited in the size of the coefficients obtained from the alternative sets of data. The results with Kosobud's data accorded more with the a priori expectations of theory. Detailed tables of these results are available upon request from the authors.

output, a Divisia index was constructed over the categories of agriculture, forestry, and fishing; construction; electricity, gas, water, transportation, and communication; the manufacturing industries of food and wearing apparel, machinery, electrical equipment; and other sector products. The Divisia weights were estimated from current value shares in the national income and product accounts.

The labor input index was obtained by aggregating over agriculture and non-agriculture labor. The latter included female and male workers with males classified by educational attainment. The weights were based on wage data. The capital services index was estimated by taking a weighted rate of growth of agricultural capital, non-agricultural, non-housing capital and housing capital. The Divisia weights for this series were based on imputed rental prices for each category of capital. The flow of services from the capital stock was obtained by applying a utilization rate, based on the ratio of electrical consumption to electrical capacity, to the stock figures for non-agricultural, non-housing capital.

The major advantage of Kosobud's data is that measures of inputs were corrected for "quality change" and rates of utilization.¹⁰ Failure to employ service-in-use measures of inputs with "embodied technical change" somehow accounted for would have resulted in biased estimates of regression coefficients.¹¹ The disaggregation of capital may have partially captured embodiment effects as the fastest growing component, since non-agriculture, non-housing capital was of the most recent vintage. Disaggregation of non-agriculture male labor by educational attainment made the labor input index reflect quality changes. The other advantages of the data are related to the properties of Divisia index numbers.

Data on nominal money balances were obtained from various issues of *International Financial Statistics*. The money stock figures were deflated by a national product price deflator. It would have been better to deflate the stock of money by a measure of factor prices since real balances affect productivity by facilitating the exchange necessary to purchase inputs. However, no suitable series for factor prices was readily available.¹²

C. Identification and the Issue of Reverse Causation

Without real money balances, there can be little question that equation (1) is a production function. A reasonable assertion is that a unidirectional line of causation runs from the inputs to output. Any feedback from output to the inputs occurs slowly and would not have a contemporaneous effect. When real balances are added to the production function, however, it may appear that one can no longer assert a priori whether (1) an increase in real balances is the result of an increase in the demand for money (due to an increase in real output), or (2) whether potential economic growth (an increase in potential real output) is due to the increase in real balances, or (3) the extent to which both (1) and (2) apply. The issue is essentially whether equation (1) is really a production function or, in fact, represents a reversed demand for money equation.

Several considerations suggest that equation (1), with real cash balances, is a production function. First, as a reversed demand for money function it would implausibly read

¹⁰ The labor input measure was not corrected for intensity of use. This is because there was little variation in hours worked per week among a wide variety of industries and occupations. See Kosobud [1974].

¹¹ The bias would be upward. For a proof which is applicable to this problem, see Kmenta [1971, pp. 395-396].

¹² See the Appendix for a full discussion of data sources and definitions.

$$(4) \quad m = f(L, K, Q, t).$$

No one has ever specified such a relation for the demand for money. There is no interest rate in (4) and the presence of L and K runs counter to virtually every argument that has been used to rationalize the demand for money.¹³ Actually, it is the presence of L and K in equation (1) that "identifies" it as a production function. No standard simultaneous equations macroeconomic model can be solved to obtain such an equation.

Second, most studies of the demand for money have found long lags in adjustment to changes in real output.¹⁴ If the changes in real balances in equation (1) were being induced by changes in real output instead of the reverse, shorter lags would be implied than have actually been found in the demand for money.

Third, the uncertainty of a priori reasoning about the role of real cash balances could also be argued for the labor input. Can an increase in output be caused by a rise in L , or are increases in L induced by rises in Q ? After all, labor services and the stock of labor can be varied quite quickly in response to changes in output. Yet, no one would argue that equation (1) is really a reversed demand for labor function.

Finally, as a further test of the direction of causality between real cash balances and real output, we applied a test suggested by Sims [1972, pp. 543-546].¹⁵ The variable for real output was regressed on future and past values of real money balances and on the contemporaneous values of labor services, capital services, and measures of technological change. Then, real money balances were regressed on future and past values of real output and on the current values of the other variables that appear in equation (1).¹⁶ If causality

¹³ Equation (4) was estimated to test for the presence of simultaneity. Using techniques suggested by Box and Jenkins [1970] the residuals from equation (4) were cross correlated with lagged income values. The results were .10, .21, .01 and -.03, for income lagged from one to four periods respectively. When $\ln Q$ is cross correlated with lagged values of the residual, the corresponding correlation values are .20, .35, .39, and .30. Since the standard error is between .243 and .267, these results indicate that there is *no* significant feedback from lagged values of $\ln Q$ to present levels of real balances. Any correlation appears to be in the reverse direction, from changes in the lagged residual to present values of $\ln Q$, evidence consistent with the hypothesis that real balances are a factor of production.

¹⁴ See Chow [1966], DeLeeuw [1967], Smith [1972], and Tanner [1969] for evidence that lags in the demand for money extend for well over a year. Although these studies were based on U.S. data, it is likely that similar results would be found for other countries. In the case of Japan, we estimated several standard versions of the demand for money and obtained as the best-fitting equation

$$(5) \quad m = -1.259 + 0.595 Q + 8.661(1/r) + 0.451 m$$

(2.88) (0.161) (2.033) (0.163)⁻¹

$$\bar{R}^2 = .998$$

$$DW = 1.98$$

$$SEE = .074$$

Period of Fit: 1955-1968

where r was the discount rate on borrowings from the central bank of Japan. All the regression coefficients were highly significant; the mean lag of adjustment was 0.8 years; and the long-run elasticities of the demand for money (evaluated at the means) of output and the interest rate were 1.061 and -0.762, respectively. The results showed virtually no change after a correction for autoregressive residuals. The degree of positive serial correlation in the residuals was low, probably because annual data were used.

¹⁵ Sims [1972] was interested in the question of unidirectional causality in a bivariate system, i.e., in a relation containing a monetary aggregate and nominal GNP. Our focus was on the causality between real cash balances and real output in a multivariate system, where other variables, about which the line of causation was not in dispute, were included.

¹⁶ Sims [1972, p. 545] points out that the problem of serially correlated residuals must be eliminated when applying the test of causality, since an F-test for the significance of a regressor's future coefficients would be invalid. Our data were annual, so we only used a single future value for the regression of real money balances on real output. For us, the t-statistic for the future variable's coefficient was relevant. However, its validity is also dependent on the absence of serially correlated residuals.

was only from real balances to real output, the future value of real money balances in the first regression should have had a statistically insignificant coefficient. If causality was in the reverse direction, the regression of real money balances on future and lagged real output should have produced an insignificant regression coefficient for the former variable.

The results were

$$(6) \quad \ln Q_t = -.01497 + .1647 \ln m_{t+1} + .08210 \ln m_t + .02297 \ln m_{t-1} \\ \quad \quad \quad (.1036) \quad (.1889) \quad (.2154) \quad (.2471) \\ \quad \quad \quad + .81081 \ln L_t + .49026 \ln K_t + .02167 t \\ \quad \quad \quad (.9395) \quad (.3396) \quad (.0465)$$

$$\bar{R}^2 = .9967$$

$$DW = 1.995$$

$$SEE = .02848$$

Period of Fit: 1954-1968

$$(7) \quad \ln m_t = -.01592 + .8983 \ln Q_{t+1} + .1057 \ln Q_t + 1.046 \ln Q_{t-1} \\ \quad \quad \quad (.1420) \quad (.3892) \quad (.4358) \quad (.4131) \\ \quad \quad \quad - 2.0811 \ln L_t - .5962 \ln K_t - .0240 t \\ \quad \quad \quad (1.034) \quad (.4605) \quad (.0697)$$

$$\bar{R}^2 = .9960$$

$$DW = 2.18$$

$$SEE = .03627$$

Period of Fit: 1954-1968

SE under coefficients

where the variables were defined as in equation (1).

According to Sims' criterion, regressions (6) and (7) show a possible line of causation from real money balances to real output, but not the reverse. In (6), the t-statistic for the coefficient of future real balances was .8719, indicating no statistical significance for that coefficient.¹⁷ In (7), the coefficient for future real output was highly significant. Equations (6) and (7) also were estimated without a time trend (t), with similar results.

Serial correlation of the residuals was not a significant problem in equations (6) and (7). Thus, neither prefiltering nor a GLS procedure was necessary as in Sims [1972, p. 545].

III. The Results

A. Production Function Findings

Table 1 shows the OLS results of estimating the CD production function containing real balances (equations (9) and (11)), time (equations (10) and (11)), both real balances and time (equation (11)) and neither time nor real balances (equation (8)). The regressions demonstrate that real money balances were a significant input in the production function for Japan. In comparison to the equation containing neither real balances or time (equation (8)), the equation containing real balances (equation (9)) indicates a substantially

¹⁷ The coefficient of $\ln m_{t+1}$ was larger than those for $\ln m_t$ and $\ln m_{t-1}$. Sims [1972, p. 545] argues that bidirectional causality may be important in practice if the future values of the independent variable have coefficients that are as large or larger than those of past values. However, all the other evidence is unambiguous. Our conclusion about the direction of causation is based on the totality of the evidence.

TABLE 1. THE PRODUCTION FUNCTION FOR JAPAN: 1952-1968

$\ln Q = \ln A + \alpha \ln L + \beta \ln K + \delta \ln m + \lambda t + u'$				
	Equation			
	(8)	(9)	(10)	(11)
$\ln A$.005 (.020)	.0132 (.0185)	- .0462 (.033)	- .0206 (.0435)
α	1.780 (.202)	1.577 (.214)	.622 (.644)	.9606 (.7477)
β	.989 (.020)	.744 (.130)	.523 (.249)	.5579 (.2531)
δ		.206 (.108)		.1281 (.1410)
$\alpha + \beta + \delta$	2.769	2.527	1.155	1.647
t			0.55 (.029)	.0327 (.0379)
\bar{R}^2	.9977	.9980	.9980	.9979
DW	1.91	2.12	1.67	1.93
SEE	.02689	.02466	.0247	.0249

$\ln Q$ =natural log gross enterprise domestic product, quantity index

$\ln L$ =natural log private domestic labor input, quantity index

$\ln K$ =natural log private domestic capital input, quantity index

$\ln m$ =natural log real money balances

t =time trend, 1952=0

\bar{R}^2 =adjusted coefficient of multiple determination

SEE=standard error of estimate

DW=Durbin-Watson statistic

Standard errors of regression coefficients in parentheses

reduced standard error or estimate, a higher adjusted \bar{R}^2 and significance on the coefficient of real money balances.¹⁸ This evidence strongly suggests that real money balances are a significant factor of production in the aggregate production function.

However, due to high collinearity, the addition of the time trend in an equation without real balances (equation (10)) and in an equation containing real balances (equation (11)) results in loss of significance on the labor coefficient in equation (10) and loss of significance on *all* coefficients, except capital, in equation (11). Thus, while the production function results presented in Table 1 suggest that real balances *are* a significant factor of production, the problem of collinearity makes it impossible to use a production function to test for other factors that might account for the relationship that we have observed between real balances and real output. A section below presents the results of tests designed to circumvent this difficult problem.

The high returns to scale found in the production function were due primarily to the size of the labor input coefficient. These large values probably reflected a downward bias in the measurement of labor services, which were augmented by a massive shift of labor from the low productivity agriculture sector to the high productivity manufacturing sector

¹⁸ A Box-Jenkins [1970] type specification analysis was performed on equation (9). Cross correlations between $\ln m$ and lags of the residual for four periods gave values of $-.001$, $-.10$, $-.09$, and $.14$. Since all cross correlation values are well below their standard errors (.25 to .28), there is no indication of simultaneity between $\ln Q$ and $\ln m$.

during 1958–1964.¹⁹ The consequence was an upward bias in the labor coefficient.²⁰

Ohkawa and Rosovsky [1968, p. 14, Table 1–4] show that productivity increases in agriculture and manufacturing were at their highest rates in modern Japanese history from 1954–1964. Furthermore, the differential in the rates of growth of the two sectors was at a record high. But between 1954 and 1964, wage increases lagged behind productivity changes in manufacturing, Ohkawa Rosovsky [1968, p. 18, Table 1–6], suggesting a downward bias in a weighted average of labor services, where the weights were based on wages. The combination of increased labor in manufacturing and wage rates that did not keep pace with productivity produced a labor service measure which grew too slowly.

The Divisia weights used to aggregate the categories of labor input were based on wages and derived under the assumption of perfectly competitive factor markets. Thus, the weighting scheme presumed an equality of wages and marginal value products at every point in time. However, it is unlikely that such an equality was maintained in Japan during the period of rapid labor migration from agriculture to manufacturing. Wages just did not adjust quickly enough to reflect the rapid increases in productivity that were occurring.

B. *Alternative Specifications of the Real Balances Variable*

Moroney [1972] has suggested that the role of money balances in production be viewed as a technical innovation rather than a direct productive input. This is a plausible view since money balances indeed might not be a factor of production in the same sense as labor and capital. To test Moroney's hypothesis, real balances were treated as a shift parameter rather than an argument in the production function. The result was

$$(12) \quad \ln Q = -.025 + 1.952 \ln L + .886 \ln K + .026335m$$

(.045) (.304) (.138) (.0345)

$$\bar{R}^2 = .9976$$

$$DW = 1.91$$

$$SEE = .02730$$

Period of Fit: 1952–1968

The regression coefficient for real money balances was statistically insignificant in this formulation. The standard error of estimate was higher in equation (12) than in equation (9). These results indicate that the specification of real money balances as a direct input (equation (9)) was superior to the one where real balances were treated as a technological innovation (equation (12)).

C. *Factors Affecting Productivity*

The production function results in Table 1 indicate that real balances were a significant factor of production for Japan. However, due to problems of multicollinearity, the role of other factors, proxied for by a time trend, was not identifiable. In this section we approach this issue from another direction by testing for various other explanations of total factor productivity. If any factors belong in the production function, they also should explain total factor productivity. Total factor productivity is the residual, calculated by Kosobud (1974) as the difference between the growth rate of output and the weighted sum

¹⁹ During the period from 1958 to 1964 the agricultural labor force showed an absolute decline while the nonagricultural labor force averaged a 980,000 increase per year. See Bluementhal [1968].

²⁰ See Kmenta [1971, pp. 395–396].

of the growth rates of labor and capital. Solow [1957] has called this variable a measure of our ignorance or "technical change." Since Kosobud's calculation of total factor productivity represented the unidentified determinants of the shifting production function and was sizable, there was presumably a process occurring which caused the production function to shift over time.

Three alternative, but not mutually exclusive, explanations of total factor productivity were tried. The first explanation was that total factor productivity depend on real money balances. The second hypothesis was that the appropriate explanatory variable to explain total factor productivity was neutral technological change (represented by a time trend). The last hypothesis tested was that total factor productivity depended on the real value of purchased (imported) technology. Table 2 shows the results.

TABLE 2. EXPLANATION OF THE "RESIDUAL" FOR JAPAN: 1955-1968

$V = \alpha_0 + \alpha_1 m + \alpha_2 T + \alpha_3 TEC$							
	Equation						
	(13)	(14)	(15)	(16)	(17)	(18)	(19)
α_0	.909 (.051)	.611 (.058)	1.035 (.024)	.734 (.058)	.997 (.026)	.936 (.067)	.948 (.077)
α_1	.347 (.016)			.160 (.051)	.091 (.039)	.084 (.040)	
α_2		.130 (.005)		.071 (.019)		.019 (.019)	.026 (.022)
α_3			.828 $\times 10^{-3}$ (.307 $\times 10^{-4}$)		.616 $\times 10^{-3}$ (.921 $\times 10^{-4}$)	.5 $\times 10^{-3}$ (.1 $\times 10^{-3}$)	.67 $\times 10^{-3}$ (.14 $\times 10^{-3}$)
\bar{R}^2	.975	.9794	.993	.9885	.995	.995	.993
DW	1.11	1.13	2.02	2.01	2.57	2.60	1.77
SEE	.081	.073	.043	.055	.036	.361	.042

V =index of total factor productivity
 m =real money balances
 T =time trend, 1952=0
 TEC =real value of imported technology
 \bar{R}^2 =adjusted coefficient of determination
 DW=Durbin-Watson statistic
 SEE=standard error of estimate
 Standard errors of regression coefficients in parentheses

Real money balances and the real value of imported technology were the *major* determinants of shifts in the production function. All variables, when entered individually, had highly significant regression coefficients.²¹ However, when the three explanatory variables appeared jointly in equation (18), the coefficient of the time trend became statistically insignificant. Thus, equation (17), with real cash balances and imported technology, gave the best result. The DW statistic indicated the hypothesis of randomly distributed residuals could not be rejected, except for equations (13) and (14), where the DW test was inconclusive.

While the results reported in Table 1 strongly suggested that real money balances were a significant input into the production function, collinearity prevented us from adequately measuring the effect of time, a proxy for other omitted factors. The results reported in

²¹ The small size of the regression coefficients for TEC was due to the units of measurement.

Table 2, however, clearly indicate that real balances and imported technology are superior to time as an explanation of total factor productivity.

Equation (9) can be used to give a rough indication of the relative importance of the three factors: labor, capital and real balances, as an explanation of the growth of the Japanese economy in the period 1952-1968. Based on the relative growth of these factors of production and their relative marginal products, our results suggest that 63% of Japanese growth can be attributed to the increase in the capital stock, over 21% can be attributed to the increase in real balances, while the remaining 16% can be attributed to the increase in the labor force. Thus, the growth of real balances played a substantial role in post-war Japanese economic development.²²

IV. *Summary and Conclusions*

This paper was concerned with a test of the hypothesis that real money balances were a factor of production in an aggregate production function for the postwar Japanese economy. Real balances release labor and capital from facilitating exchange to more specialized productive tasks, thus enhancing productivity.

Variants of an unconstrained CD production function containing measures of labor, capital services, real money balances, and a technical progress shift parameter were estimated for the period 1952-1968. The data for output, labor and capital were developed by Kosobud [1974], who essentially followed the methods of Christensen-Jorgenson [1970] in calculating Divisia indices of these variables.

The evidence showed that real cash balances were a significant input in the production function of Japan. There was no evidence to support the notion that real balances act as a technological innovation, as suggested by Moroney [1972]. Specifying the real cash balances as a shift parameter led to an insignificant regression coefficient for that variable.

To examine the possibility that the importance of real balances was due to reverse causation, the Sims [1972] test for unidirectional causality was applied. The results of this test suggested a line of causality from real balances to real output, rather than the reverse, supporting the hypothesis of a production function with real cash balances as an input.

As a final test of the relative importance of alternative explanations of the increase in productivity, total factor productivity (measured as a residual) was regressed on real balances, a measure of borrowed technology, and on a time trend. The role of borrowed technology was suggested by Ohkawa and Rosovsky [1968, pp. 28-30] and Kosobud [1974] as important in the postwar economic growth of Japan. The time trend was used as a proxy for neutral technological progress. The results indicated that real money balances and the real value of imported technology provided the major explanation of the residual, with the time trend coefficient insignificant when all three variables were in equation (18).

²² This calculation assumes that the marginal physical products of all inputs remain the same. Using the coefficients reported in equation (9) we calculated how much real output would fall if the level of each factor was held respectively at the 1952 level while all other factors were allowed to grow to their 1968 level.

APPENDIX

Definitions of Variables and Sources of Data

- Output:* Defined as a Divisia quantity index number of gross enterprise national product. The source was Kosobud [1974, p. 114, Table 1 of the appendix, column 1].
- Labor:* Defined as a Divisia quantity index number of private domestic labor input. The labor input was measured as the employed labor force in agriculture and nonagriculture. The latter category was adjusted for sex and by level of educational attainment by males. The source was Kosobud [1974, p. 114, Table 1 of the appendix, column 3].
- Capital:* Defined as a Divisia quantity index number for private domestic capital input. Capital input was measured by capital stocks for agriculture, housing, and nonagriculture, non-housing capital stock. Weighting by estimates of rental prices reflected "quality change." The source was Kosobud [1974, p. 114, Table 1 of the appendix, column 2].
- Real Money Balances:* Defined as the money supply deflated by a price deflator for national product. The money supply was currency outside banks plus demand deposits. The source for the money supply was *International Financial Statistics*, Annual Data, various issues. The sources for the price deflator was the Institute of Economic Research, Economic Planning Agency, Government of Japan, *Economic Analysis*, Vol. 27, March 1969, pp. 42-43.
- Interest Rates:* Defined as the discount rate of the central bank of Japan. The source was *International Financial Statistics*, annual average of quarterly rates.
- Total Factor Productivity:* Defined as the difference between the growth rate of output and the weighted sum of growth rates for the inputs. The source was Kosobud [1974, p. 114, Table 1 of the appendix, column 4].
- Time:* Defined as $t=0$ in 1952 and numbered consecutively to 16 in 1968.
- Real Value of Imported Technology:* The nominal value of imported technology was defined as yen expenditures for licenses, royalties, patents, etc., in the technological balance of payments. The source was the "White Paper on Science and Technology," Science and Technology Agency, Government of Japan. Discussed in Kosobud [1974, pp. 33-36, manuscript]. The deflator was the price deflator for national product.

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