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Title: A DYNAMIC MODEL OF EXCHANGE RATE IN RELATION TO INTERNATIONAL TRADING

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It is popular belief that the volatility of the exchange rate is due to the balance of payments, which in turn is mainly influenced by the balance of trade. A closed-loop dynamic economic model is proposed to describe and analyse the effect of the international trade of a country on the relative stability of its foreign exchange rate is seen to be moderated by a country's inventory. The inventory level is related to the supply (exports) and demand (imports), with the close monitoring of the monetary authority. The monetary authority, seeking to maintain a desired inventory level, would set the desired exchange rate. This behavior is at the same time influenced by the desire for relative stability of the exchange rate.

Japan's domestic economy, international trading, and exchange rate for the period (1960-1970) are used to simulate the model. The open-loop simulation of the model is first investigated. Two versions

of closed feedback network of the model are simulated and compared. The simulations demonstrate the applicability of the model. The model projects, a tool, a dynamic method.

A Dynamic Model of Exchange Rate In Relation
To International Trading

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GLOSSARY

Analog computer: A computer which handles information in continuous form only.

Bretton Woods: At the suggestion of United States President F. D. Roosevelt, representatives of forty-four nations convened at Bretton Woods, N. H., July 1-22, 1944, for the United Nations Monetary and Financial Conference. To promote post-war reconstruction and resource development and international trade and avert monetary chaos, the Conference drafted the Articles of Agreement of the International Bank for Reconstruction and Development and of the International Monetary Fund to assist international capital investment and monetary stability.

Digital computer: A computer which handles information in digital form only.

Elasticity: A term employed to indicate the degree of change in the quantity of goods demanded and supplied in response to price changes.

Forward exchange: The procedure involved in buying or selling foreign exchange for future delivery.

Hedging: The purchase or sale of exchange, spot or forward, to meet the exchange risks that affect the values of foreign-currency-denominated assets and liabilities. (Also, the taking of an exchange risk to offset a larger risk in the opposite sense.)

Hybrid computer: A computer which embodies both analog and digital elements.

Hybrid simulation: One in which a hybrid computer is used to simulate in both continuous and discrete quantities.

Interest arbitrage: The act of transferring money from one country to another country to take advantage of differing rates of interest in the two countries.

Par: The official rate of exchange established by a government with the agreement of the IMF (International Monetary Fund).

Special Drawing Rights: A new reserve asset to be used in international exchange transactions as a supplement or substitute for gold or reserve currencies (dollar and pound), hence, sometimes called paper gold.

Spot exchange: The purchase and sale of a foreign currency for immediate delivery and paid for upon delivery.

A DYNAMIC MODEL OF EXCHANGE RATE IN RELATION TO INTERNATIONAL TRADING

I. INTRODUCTION

> "Ignorance turns into hunch,
> hunch into belief,
> and, ultimately, belief into knowledge." (10)

After decades of relative neglect, economic theory, especially in its mathematical form, has taken new life since the advance of computers. The renaissance has included many aspects of international economics. Most of the major advances in economic theory have been based on the assumption of a closed economy. The pure theory of international trade, in spite of outstanding contributions here and there, is not very rich in content and is rather narrow in its range. Even when advanced techniques and methods have been developed in other branches of economics, trade theorists have often been slow to adopt and apply them in exploring new grounds.

Although the interrelationship between exchange rate and international trade via balance of trade, is one of the oldest themes in economics, until very recently there have been very few well-developed dynamic (as opposed to comparative-static) models in the literature. To quote from Haberelers's survey (11), p. 58:

> "As far as abstract theory is concerned there exists, however, not much more than occasional hints

and programmatic theory plus a few fumbling steps in the direction of the actual construction of dynamic models. Those who believe that it is possible to set up model sequences of economic development should go ahead and do it, instead of merely criticizing others for not having done it."

To quote from another survey by Caves (2), p. 242:

"Constructing models of international trade which involve time in some essential way (this is what we shall take 'dynamic' to mean) has become an activity uniformly approved but seldom practiced with success."

We have taken these statements of admonition and advice seriously.

Bhagwati (1) also aptly comments in his survey:

"In contrast to the general richness and synthesized character of much of pure theory in its comparative statics, dynamic propositions in international trade are comparatively few and bear no trace of any uniform design, each having been developed in virtual isolation. Dynamic trade theory, where it exists, has grown up in an essentially ad hoc fashion and has witnessed none of the inter-action of analysis which usually accompanies the development of an area of knowledge and produces a common design, a unifying frame."

One of the main purposes of this study, which is described in its title and delimited by its size, is to consider some aspects of the impact of the pattern of international trading in terms of a very simple but roughly "unifying" framework. It is an outline of the theory of the rate of exchange, concise in form and elementary in approach. The simulation model, which is not entirely trivial or useless, addresses some of the questions asked, such as, what is the relationship between international trade and exchange rate? What is the role of the central authority in this relationship? Can a dynamic model be constructed and simulated? These are important questions for understanding a growing international trade. To solve these questions, the approach that is taken in the paper is a combination of two disciplines. The important concepts are extracted from the economic theory and the functional relationship between these concepts are joined. The practice in control system theory is then applied to construct a model. The model is simulated on the computer. The relationship between international trade and exchange rate is mainly established in Chapter II. A dynamic model is constructed in Chapter III. In the model, the control of central authority is introduced. In Chapter IV, the model is simulated on the computer. Japan's exchange rates and international trading (1960-1970) are utilized. The open-loop simulation is performed first.

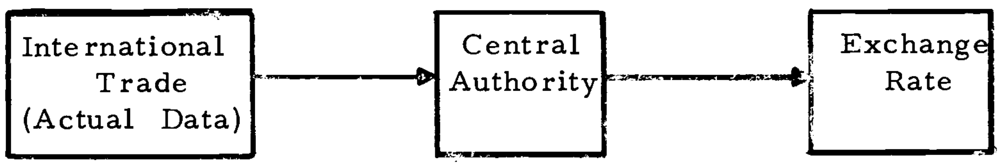

Figure 1-1. Forward path.

The open-loop simulation, as in Figure 1-1, is a forward path. From the actual data of international exports and imports, through the inventory control of central authority, exchange rates are generated. Then two versions of closed-loop, feedback simulations are performed. The actual data of international trade in the forward path are replaced by results from exchange rate dependent equations as developed in Chapter II. This completes the closed-loop feedback network as in Figure 1-2.

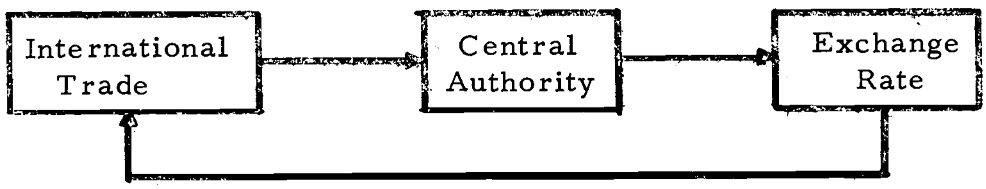

Figure 1-2. Feedback path.

From this combined effort, the questions asked are answered. The following is a quote from Hahn-Matthews (9):

> "Different contributors to the theory of growth have differed a good deal in their views about the aims of the exercise. This makes for difficulty in drawing conclusions about how far the aims have been realized. Some authors have tried to construct models which, though simplified as any mold model must be, do correspond to the most important features of reality, and they have proceeded to draw inferences about the explanation of observed events and about policy. Others have been less ambitious and have viewed their models as illustrations of how an economy <u>would</u> move on certain assumptions, in the hope that understanding of the laws of motion of their imaginary

> world might cast light, even if only by analogy, on the laws of motion of the infinitely more complex world of reality."

As these limitations may be interpreted in various ways, some preliminary discussion of the field, such as in Chapter II, cannot be dispensed with if the scope and the purpose of the analysis offered in it is to be properly understood. In the course of the discussion, some general relations may also be explained which are quite fundamental to the theory that follows.

In Chapter III, the model is formulated which belongs to the old tradition of conceptual, box-of-tools economics. It shows how complex phenomena can be split into component parts, and how the knowledge of the relations existing between the latter may be used to throw light on the nature and the origin of the former. The model is particularly concerned with examining the interconnections between a few variables that seem to be strategic.

This effort is an advance on the old, conceptual tradition. The advance, however, is not so much in rank as in succession. It is not from something inferior to something superior; it is rather from something vague to specific. For if propositions are to be proved and hypothesis tested, they must first be formulated. The elements which go into them must be defined and possible relationships between them explored. The tool in the box of conceptual economics is thus needed to start the advance. And as the field is unknown and the progress uncertain, one dares not discard and abandon this preliminary step. This is the first limitation of the thesis. The analysis discussed in Chapter III does not go beyond the stage of defining concepts and exploring possible relations between them. In this initial effort, frictions and disturbances (such as tariffs, speculation effect, and capital flow, etc.) are disregarded in order to be able to concentrate the analysis on the dominant forces (exports and imports) that characterize international trading. In other words the theory is about the aggregates of all goods exported, of all goods imported, and all foreign countries aggregated into one "rest of the world", forming the so called two nations model. The system discards entirely the classical notion of gold movements, as stipulated in the Bretton Woods system, and consequent adjustments in the internal price levels of the trading countries. Nor do we abide by SDR (Special Drawing Rights). However, we do include the inventory concept (6) as a means of control by central authority.

In Chapter IV, the model is simulated with Japan's exchange rate and international trading. To build more complex models and test them econometrically and simulate them on the computer is immensely laborious work. One of the great difficulties is in seeking reliable and meaningful data, as this is amply demonstrated within Chapter IV.

The analysis could be developed further in the direction of either greater rigor or greater empirical content. One of the aims of this work is to give a simple formal shape to some of the ideas often loosely discussed in the literature on trade and exchange rate. The focus is on analytic development of selected issues, a few empirical insights, and some comprehensiveness of treatment. In a field in which vague generalities abound, data are scarce and inaccurate, this may not be an entirely fruitless exercise. It is hoped that through such a pragmatic short-cut model, some rough answers to the relevant questions as indicated previously will be provided. At this point, one can almost hear his prospective reviewer pronouncing the ultimate judgment: "the author has resoundingly fallen between two stools".

II. THEORY OF INTERNATIONAL TRADE AND EXCHANGE RATE

2.1 General Theory

The most enduring, universal, and dominant link between one country and the rest of the world is international trade. International trading in turn demands a common denominator (parities) between the countries. The determination of (common denominator) parities under the gold standard presented no problem, but under a paper money standard, which prevails universally today, it presents a number of difficulties. Paper money, whether government currency or commercial bank demand deposit, has no intrinsic value and is a form of debt. The value of paper money on the domestic market is generally held to be determined by what the money will purchase there. Hence, the value of the paper money rises when prices decline and declines when prices rise. On the international or foreign exchange markets, the value of a national market money may be said to be determined by the amount of foreign currency that can be obtained in exchange for the currency. The foreign currencies are valued for the command they give over tradable goods and services. The value of the currency rises when more foreign currency can be obtained and falls when less can be obtained. However, this does not say much about how exchange rate is determined. The exchange rate is mainly determined by the market's influence and as well as by the monetary authorities of the country. The monetary authorities of the country adopt the most intelligent combination of budgetary and monetary policy conceivable, which as a rule will not be sufficient, to permit the attainment, simultaneously, of the three aims of:

(a) balance-of-payments equilibrium

(b) full employment, and

(c) an unchanged price level.

If the first two are realized, it appears the third cannot be. A country with a balance-of-payments deficit will not, as a rule, be able simultaneously to realize all of the three aims stated above. One of the dominant forces within the price structure is the exchange rate. The theories that purport to explain the levels and movements of parities both in spot and forward exchange rate have been somewhat neglected.

The two leading theories of explaining the determination of the exchange rate, besides the Speculative theory of Capital Flows and Interests Arbitrage, are the Purchasing Power Parity theory, and the Balance of Payments Equilibrium theory.

A. Speculative Theory

In the international transfers of capital, the discipline involved is so broad, mysterious, and fascinating, that each topic requires the concentration of specialists. Some of the explanations of the short term capital flows are briefly discussed in the following paragraphs.

Capital Flight. At times of great political and economic insecurity, owners of capital are likely to want to transfer their funds abroad for safety. Although once they have transferred them, they will doubtlessly sooner or later invest them in earning assets, considerations of income have nothing to do with the original capital movement. It is motivated by fear. It was estimated that in 1935-1939 well over 5 billion dollars[1] were transferred from Europe to the United States.

Speculative Capital Movements. This kind of international transfers of capital aims at profiting from an increase in the value of the principal, rather than earning an income. The common objective is not having foreign assets. The holdings of some country's currency is in the expectation of the appreciation of that particular currency in the near future. These speculative movements can, and have, at times exerted tremendous pressure on the supply, or the demand, of the currency.

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[1] Dollars referred to are United States Dollars unless otherwise specified.

Interest arbitrage. The interest arbitrage theory is the most widely accepted explanation of the magnitude of forward exchange rates. It is based on the fact that short-term interest rates differ from country to country. To take advantage of higher interest rates, institutions like banks, mutual funds, insurance companies, and oil companies, invest on a short-term basis. The empirical discussions of forward exchange and interest arbitrage are explained in various books by Paul Einzig (4). A distinctive mathematical formulation of the forward exchange market, due to interest arbitrage, is introduced by Tsiang (15). Tsiang's equations are expressed in static form. The speculation in the forward exchange, hedging in connection with foreign trade, as well as implications for forward exchange policy are discussed in Tsiang's paper.

An explicit model of forward exchange in static equations has been explored by Grubel (8). He went through a simulated exercise of speculation in forward exchange with a simple method of speculation. The book shows great skill of piecing together bits of evidence of the real world in deriving relevant parameters. It lacks analytical interpretations to substantiate the theory.

Since the speculative theory is beyond the scope of the present study, it's importance in determining the exchange rates is emphasized; but will not be investigated any further.

B. Purchasing Power Parity

The purchasing power parity theory was first fully described during the 1800's. The theory demonstrates, for example, if $100 will buy in the United States a bundle of goods equal to what 300 Yen will buy in Japan, the purchasing power par, or basic equilibrium rate is 3 Yen per Dollar. If however, it takes 500 Yen to buy the quantity of goods that $100 will buy in the United States, then 5¥/$ is the parity rate. Any attempt to measure the absolute level of purchasing power par at any given moment would flounder on the impossibility of obtaining a sufficiently wide variety of goods that is fully representative of consumption patterns in the two countries and that are common to both countries. Instead of this absolute approach, the comparative approach is usually used. That is, the relative level of prices in two countries in a given year is compared with their relative level in a base year, the latter ideally being one when the balance of payments was in equilibrium relationship, i.e., that each country's external accounts are balanced.

Thus if in 1965 Japan's balance of payments was in equilibrium and the exchange rate was 4¥/$, then in 1975, if prices in Japan had risen 20% and in the United States by 30%, the purchasing power par rate for the latter year would be:

$$4 \times \frac{120}{130} = 3.70$$

The formula that is often used to compute the purchasing power parity rate is:

$$\frac{\text{Index number of prices in one country}}{\text{Index number of prices in another country}} \times \begin{array}{l}\text{rate of exchange in base period}\\ \text{between the two countries}\end{array} = \begin{array}{l}\text{purchasing power}\\ \text{parity rate}\end{array}$$

Departures from such a rate are, of course, possible and almost certain, as mentioned in the beginning of the chapter, owing to the varity of influences affecting a country's interests. But underlying these, disturbing forces, such as price levels of one country compared to other countries, are exerting constant pressure to bring the exchange rate to a level expressing a parity of purchasing power. If the current exchange rate does not reflect the rate that makes the purchasing power of two currencies equal, price differences in the two countries would attract or repel trade and push the exchange rate toward purchasing par. Thus if Yen/dollar rate of exchange is 3¥/$ but the price level in Japan is such that it takes 400 Yen to buy as much as $100 will buy in the United States, goods in the latter will be bargains and will attract buyers in Japan, while residents of the U.S. will avoid purchasing in Japan. These reactions, transformed to the foreign exchange market, cause the dollar to appreciate, the Yen to depreciate, until a new rate is established.

There is no denying the fact that the lines of causation between prices and exchange rates goes both ways; from prices to exchange rates, and from exchange rates to prices. If the influence of changes in prices of exchange rates were predominant, the theory of purchasing power parity would be invalid, for it asserts the dominance of the opposite direction of causation.

However, the purchasing power parity doctrine, is not merely a formula for calculating precise equilibrium rates. More basically, the doctrine is to equalize the purchasing power of several currencies, hence it describes the stabilizing pressures that keep an exchange rate from oscillating chaotically. The purchasing power parity instead keeps pushing it toward a definite equilibrium level. The corrective pressure would operate not merely through changes in the volume of trade in a given list of goods and services but also through changes in the composition of that list. This evolved a long list of time variant prices, and induces the difficulty in determining just which index of prices should be employed. Usually, in practice, many indices are used in an effort to provide a reliable basis for the calculation.

Nevertheless, Yeager (17) reported that despite many statistical sources of inaccuracy, and the presence at any particular time of distorting forces, various measurements of the correspondence between purchasing power par and actual fluctuating exchange rates have been shown to be fairly high. In the period 1920-29, the Spanish peseta kept within a range of plus or minus 12.5% of purchasing power par in 82.5% of the months involved, and the Canadian dollar between 1950 and 1956 stayed within 3.5% of parity (using wholesale price indexes) in all but 4% of the months. For a fuller analysis of the purchasing power par doctrine, see Yeager (17).

Recent work of Gailliot (7) emphasized also that the price changes are the primary determinant of the exchange rate. He allowed for important secondary factors such as tariffs and other trade hindrances. He tested the Purchasing Power Parity theory with eight countries (United States, Canada, Japan, United Kingdom, France, Italy, Switzerland, and Germany). He chose the two five-year periods of 1900-1904 and 1963-1967 because, preceding these periods, long intervals of relative peace and prosperity were maintained. This he argued would likely minimize the expectation of major disturbances in the international economic environment. He concluded:

> "In spite of the admitted problems in the data, the results of this study lend support to the Purchasing Power Theory as a long-term hypothesis of international economic."

C. Balance of Payments

The deficiencies in the purchasing power parity theory led to the elaboration of a more modern theory that has wide acceptance today: the balance of payments equilibrium theory. The theory is expressed by John Stuart Mill (14):

> It may be considered, therefore, as established, that when two countries trade together in two commodities, the exchange value of these commodities relative to each other will adjust itself to the inclinations

> and circumstances of the consumers on both sides, in such a manner that the quantities required by each country; of the articles which it imports from its neighbors, shall be exactly sufficient to pay for one another.

According to the theory; the rates of exchange of any country with other countries, on free markets, will tend to establish themselves at a point that will result in a balance of payments equilibrium. Actually, this is less a theory than a truism. On free exchange markets, the rate of exchange could scarcely establish itself at any other point.

The most important difficulty with the theory has been the impossibility of computing such a rate for countries with a wide variety of international transactions.

D. Evaluation

The practical advantage of the purchasing power parity theory over the equilibrium theory is, therefore, the possibility of computing a rate, and consequently a par, that has at least approximate accuracy. However, even the most carefully estimated rates, whatever the method employed, are subject to a wide margin of error because of inaccuracy of many economic data. Even the most precise economic statistics, such as those for foreign trade, are inaccurate.

The known inadequacies of the "two" theories described here have recently led several countries to experiment with another method of determining an appropriate par. The rate of exchange was allowed to fluctuate more freely until the the data accumulated were sufficient to enable the exchange authorities to determine what the correct par should be. In several cases there was some degree of manipulation by the authorities to limit the exchange rate fluctuations. In theory, the ideal rate, or that which occurred most frequently, should be selected as the proper one to use as the new parity.

It is concluded that the purchasing power parity rate of exchange does have the single advantage, of being relatively determinable, whereas other theories do not provide a practical method of calculating an exchange rate or a par value. In addition, since merchandise trade dominates the world's interaction, the theory does have at least limited applicability. For such reasons as these, the purchasing power parity is as a workable approach to the general movement of exchange rates. The integration of prices or exchange rate into imports and exports will be explored in the next section.

2.2 Export and Import Equations and Exchange Rate

After an exposy of the general theory of international trade, the mathematics associated with the theory will be introduced. The purchasing power parity or the exchange rate will be brought into the modeling. The approach in formulating the export and import equations will be in the same format of Houthakker-Magee (12), and Ujiie-Yeung (16).

According to Houthakker-Magee:

"The total import equations (1) regress the value of total imports (in millions of dollars) deflated by import prices for each country on an index of country real gross national product (1958=100) and the ratio of import prices to domestic wholesale prices in the country. ... The total export equations (2) regress the value of each country's total exports (in millions of dollars), deflated by its import price index, on an index of "world income" in 26 of its country markets (1958=100), and on the ratio of the country's export prices to 'world export prices' for the other countries."

The equations (1) and (2) mentioned in their paper are:

$$(1)\ \log M_{it} = A_i + A_{1i} \log Y_{it} + A_{2i} \log (PM_{it}/WPI_{it}) + U_{it}$$

$$(2)\ \log X_{jt} = B_{0j} + B_{1j} \log YW_{jt} + B_{2j} \log (PX_{jt}/PXW_{jt}) + V_{jt}$$

M_{it} = i^{th} country's imports of merchandise during year t

Y_{it} = an index of the country's GNP

PM_{it} = price index of imports into the i^{th} country

WPI_{it} = the country's wholesale price index

A_{1i} = elasticities with respect to income

A_{2i} = elasticities with respect to price

U_{it} = error term

A_i = constant

X_{jt} = j^{th} country's exports of merchandise to all other countries during year t

YW_{jt} = an index of GNP for 26 importing countries (excluding country j)

PX_{jt} = an index of country j's export prices

PXW_{jt} = an index of export prices of 26 other exporting countries

V_{jt} = error term

B_{0j} = constant

B_{1j} = elasticities with respect to income

B_{2j} = elasticities with respect to price

Ujiie-Yeung utilized the same equations, but in the form of import and export indexes, prices indexes, and indexes of incomes. They regressed the equations in aggregate form first, such as using the import and export wholesale prices. They then took the disaggregate approach by using values of prices of different sectors of the trade such as textiles, foodstuff, machinery and others. Both Houthakker-Magee and Ujiie-Yeung stress the practical and theoretical importance of price as well as income.

In generating imports and exports, the ratio of current exchange rate to the par exchange rate at first, is concatenated to these import and export equations. But after a realistic examination of the theory indicated in Section 2.1, the compounded equations, and the results of the regressions of these modified equations, the following equations are formulated.

$$\log IM(t) = A_0 + A_1 \log Y(t) + A_2 \log \left(\frac{R(t)}{R(0)}\right) + U \qquad 2.1$$

$$\log EX(t) = B_0 + B_1 \log YW(t) + B_2 \log \left(\frac{R(t)}{R(0)}\right) + V \qquad 2.2$$

A_0 = constant

B_0 = constant

A_1 = income elasticity for the country

B_1 = income elasticity for the rest of the nations

A_2 = exchange rate elasticity for the country's imports

B_2 = exchange rate elasticities for the country's exports

U = error term

V = error term

R(t) = current exchange rate

R(0) = par exchange rate

Y(t) = yearly income of the country

YW(t) = yearly income of the rest of the nations

IM(t) = imports

EX(t) = exports

The above equations replace the terms of prices in equation (1) and (2) by the terms of exchange rates. Throughout the paper, the logarithmic equations are used because of their generally superior fit and ease of interpretations.

The period investigated by Houthakker-Magee and Ujiie-Yeung's are respectively (1951-1966) and (1953-1967), while the current study is (1960-1970). The results of regression for Japan are listed in Table 2-1. While the data, in Appendix I, and format (see also Chapter III and IV) used in this study are completely different from either parties, a comparison of the results justifies the reliance on the proxy measure of exchange rates.

Table 2-1. Comparison of elasticities for Japan.[1]

	A_{1i}	B_{1j}	A_{2i}	B_{2j}
			(For Price)	
T. C. Chang (3) (1924-1938)	1.35	1.08	-0.47	-0.60
Houthakker-Magee (1951-1966)	1.23 (13.06)	3.55 (14.82)	-0.72 (-2.40)	-0.80 (-1.78)
Ujiie-Yeung (1953-1967)	1.38 (18.71)	3.17 (8.80)	0.17 (0.41)	-0.72 (-0.89)
	A_1	B_1	A_2	B_2
			(For Exchange Rate)	
Current Study[2] (1960-1970)				
Simulation A	0.85 (25.96)	1.79 (21.08)	1.65 (0.55)	-0.45 (-0.10)
Simulation B	0.81 (25.55)	1.77 (17.85)	0.83 (0.28)	2.95 (0.57)

[1] The number in parenthesis below each coefficient is t-ratio.

[2] See Chapter IV, Simulation A and Simulation B.

III. THE DYNAMIC MODEL

3.1 The Model

In this chapter, a macro-economic model of international trading is formulated explicitly in the area of exports and imports. The model is continuous and dynamic in nature. It incorporates the inventory concept of the central authority. The inventory is a balance of external trade. A time-moving model is used to analyze these questions because economic growth alters the underlying relation between the trade and exchange rate as time progresses. The dynamic continuous model is illustrated in Figure 3-1.

The change of a country's inventory level depends on the deficit or surplus of its external trade. When these changes accumulate over a period of time, they become the country's accumulated inventory. This process expressed in the mathematical form would be the following equation:

$$\overset{o}{\underline{\Phi}}(t) \quad = \underline{EX}(t) = \underline{IM}(t) \qquad 3.1$$

where $\underline{EX}(t)$ = exports of goods in dollars (discussed in Section 2.2)

$\underline{IM}(t)$ = imports of goods in dollars (discussed in Section 2.2)

$\overset{o}{\underline{\Phi}}(t)$ = change in inventory level

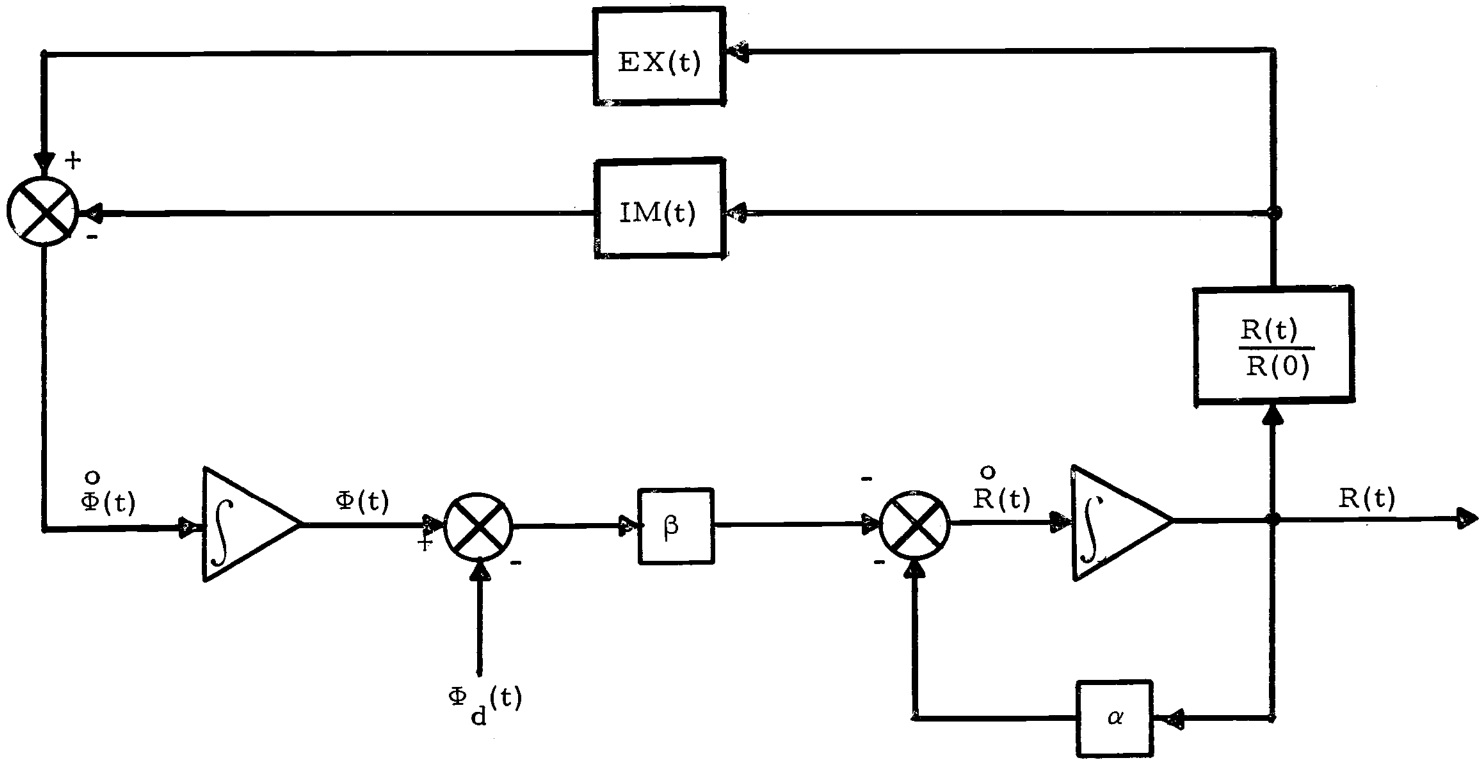

Figure 3-1. Block diagram for the model.

In order to adopt the most intelligent combination of budgetary and monetary policy conceivable, the country's monetary authority would set a desired inventory level to control its external trade. It is conceived that the difference between the market inventory level and the central authority desired inventory level would change the value of the currency, consequently the price level. Furthermore, the price level would tend to support itself under certain circumstances, i.e., in peace and prosperity. This established the equation:

$$\overset{o}{\underline{R}}(t) = \alpha\, \underline{R}(t) - \beta\, [\underline{\Phi}(t) - \underline{\Phi}_d(t)] \qquad 3.2$$

$\underline{R}(t)$ = exchange rate

$\overset{o}{\underline{R}}(t)$ = change in exchange rate

$\underline{\Phi}_d(t)$ = desired inventory level

$\underline{\Phi}(t)$ = inventory level

α = exchange rate adjustment coefficient

β = inventory adjustment coefficient

The inventory level $\underline{\Phi}(t)$, corresponding to the classical inventory notion, strives to maintain a desired inventory level $\underline{\Phi}_d(t)$, rather than to fluctuate freely.

A. Exports and Imports

The least-square fitting is used to generate the elasticities in Equation 2.1 and 2.2. The equations written in state-space form are:

$$\begin{bmatrix} \log \underline{IM} & 0 \\ 0 & \log \underline{EX} \end{bmatrix} = \begin{bmatrix} A_0 & 0 \\ 0 & B_0 \end{bmatrix} + \begin{bmatrix} A_1 & 0 \\ 0 & B_1 \end{bmatrix} \begin{bmatrix} \log \underline{Y} & 0 \\ 0 & \log \underline{YW} \end{bmatrix} + \quad 3.3$$

$$\begin{bmatrix} A_2 & 0 \\ 0 & B_2 \end{bmatrix} \begin{bmatrix} \log (\underline{R}/R(0)) & 0 \\ 0 & \log (\underline{R}/R(0)) \end{bmatrix} + \begin{bmatrix} U & 0 \\ 0 & V \end{bmatrix}$$

A_0 = constant

B_0 = constant

A_1 = income elasticity for the country

B_1 = income elasticity for the rest of the nations

A_2 = exchange rate elasticity for the country's imports

B_2 = exchange rate elasticities for the country's exports

U = error term

V = error term

$\underline{R}$ = current exchange rate

R(0) = par exchange rate

$\underline{Y}$ = yearly income of the country

$\underline{YW}$ = yearly income of the rest of the world

$\underline{IM}$ = imports

$\underline{EX}$ = exports

B. Inventory

From Equation 3.1 the difference between the exports $\underline{EX}(t)$ and imports $\underline{IM}(t)$ is the change in inventory $\overset{o}{\underline{\Phi}}(t)$. The change in inventory is smoothed and accumulated by applying Simpson's 3/8 rule. The result is designated as that of the market inventory level $\underline{\Phi}(t)$

$$\underline{\Phi}(t) = \int_{t_0}^{t_0+nh} \overset{o}{\underline{\Phi}}(t)dt + \Phi(0) \qquad 3.4$$

$$= \frac{3h}{8}[\overset{o}{\Phi}(t_0) + 3(\overset{o}{\Phi}(t_1) + \overset{o}{\Phi}(t_2) + \overset{o}{\Phi}(t_4) + \overset{o}{\Phi}(t_5) \ldots + \overset{o}{\Phi}(t-1))$$

$$+ 2(\overset{o}{\Phi}(t_3) + \overset{o}{\Phi}(t_6) \ldots + \overset{o}{\Phi}(t-3)) + \overset{o}{\Phi}(t)]$$

$$+ \Phi(0)$$

where $\Phi(0) = 0.0$

$t = t_0 + nh$ $\quad n = 1, 2, 3 \ldots$

h = unit interval year / month

Simpson's 3/8 rule is applied here to average the small changes on the curves as a reflection of ignoring the minor disturbances in reality. The desired inventory level $\underline{\Phi}_d(t)$ is designated as the average of the last twelve market inventory levels.

$$\underline{\Phi}_d(t) = \frac{\sum_{n=t-12}^{t} \underline{\Phi}(n)}{12} \qquad 3.6$$

The number twelve is selected as it designates total months of a fiscal year.

The difference between the market inventory level and the desired inventory level indicates the variance of the estimation of the central authority and the actual market effect. This in turn causes a change in the rate of exchange rate by the parameter $-\beta$.

For desired inventory level $\underline{\Phi}_d(t)$, various schemes have been used. One of the more elegant methods investigated is the method of distributive lags in expectations about the future. The crux of this method is described by the following equation,

$$\underline{\Phi}_d(t) = \gamma \underline{\Phi}_d(t - 1) + (1 - \gamma)\, \Phi(t) \qquad 0 \leq \gamma < 1 \qquad 3.7$$

If γ is zero, then $\underline{\Phi}_d(t)$ equals $\Phi(t)$ which means the desired inventory level coincides with the current market inventory level. This level of inventory may or may not be the desired level of the central authority. If γ is one, then there is no change in the desired inventory level from the last period. However, if this method is performed repetitiously over a period of time, it would include every $\Phi(t)$ with corresponding weights attached to it. This is a very undesirable condition as the changes in inventory level and the desired inventory level would undoubtedly be more independent, after a period of time, of their prior levels.

C. Exchange Rate

In the period of peace and prosperity, the exchange rate would tend to support itself regardless of the short duration of the actual trade position. Rewriting Equation 3.2, in state space form

$$\overset{o}{\underline{R}}(t) = [\ -\alpha\ -\beta]\ \begin{bmatrix} \underline{R}(t) \\ \underline{\Phi}(t) - \underline{\Phi}_d(t) \end{bmatrix} \qquad 3.8$$

Again Simpson's 3/8 rule is applied to smooth and accumulate the changes of exchange rate so that the future exchange rate is

$$\underline{R}(t+1) = \int_{t_0}^{t_0 + nh} \overset{o}{\underline{R}}(t)dt + R(0) \qquad 3.9$$

$$= \frac{3h}{8} [\ \overset{o}{R}(t_0) + 3(\overset{o}{R}(t_1) + \overset{o}{R}(t_2) + \overset{o}{R}(t_4) + \overset{o}{R}(t_5) \ldots + \overset{o}{R}(t-1))$$

$$+ 2(\overset{o}{R}(t_3) + \overset{o}{R}(t_6) + \ldots + \overset{o}{R}(t-3)) + \overset{o}{R}(t)]$$

$$+ R(0) \qquad 3.10$$

where $R(0) = 362.0$

$t = t_0 + nh$ $\qquad n = 1, 2, 3 \ldots$

h = time interval $\quad$ year / month

The future exchange rate then is in turn affecting the future exports and imports.

IV. SIMULATION

4.1 Simulation is Wha-a-at?

The word "simulation" means different things to different people. According to Webster's Unabridged, simulation means, among other things, " ... a profession meant to deceive ... a counterfeit ... a fraud ...". According to McLeod (13) in Volume 1, Issue 1 of SIMULATION, he defined:

> "Simulation is the act of representing some aspects of the real world by numbers or symbols which may be easily manipulated to facilitate their study."

Simulation in this study is the application of the model, developed in Chapter III, on the digital computer CDC 3300, for the study of the international trade of Japan (1960-1970). In the beginning of this study, hybrid simulation was considered. Due to the limitation of the facilities and the difficulty of scaling imposed by the nature of the problem (national income of Japan is measured in billions while exchange rate is in hundreds), digital simulation is utilized. Instead of employing any of the existing simulation languages, FORTRAN is used to give additional versatility in programming. The Programs are listed in Appendix II.

4.2 Open-Loop and Closed-Loop Systems

The open-loop system represents a processing of input signals to provide an output signal with an amplification. The input-output relation represents a cause and effect relationship of the process. For example, if the limited cultivation of Japan necessitates her to import a definite amount of food from the United States regardless of price or exchange rates. This is an open-loop system.

In contrast to the open-loop system, a closed-loop feedback system utilizes an actual output of the system to generate the input. In the example above, if Japan's quantity and quality of import of food becomes sensitive and fluctuates according to the level of price or exchange rates, this becomes a feedback closed-loop system.

A closed-loop system is generally characterized by the dynamics of the system, which are best described in terms of stability and response. Stability is the measure of a system's inherent tendency to be self-restoring. A stable system, when acted upon, eventually assumes a finite output, called the steady state. The steady state itself may be a displacement or a higher-order function. An unstable system's output eventually becomes infinite in magnitude. The response feature of dynamic performance indicates how effectively the finite output is achieved. Response applies only for stable system and are nonexistent for unstable ones.

It should be noted that the stability of a closed-loop system is not guaranteed when transformed from a stable open-loop system. The closed-loop system, so formed, is usually unstable.

4.3 Yearly Exports and Imports

Japan's domestic economy, international trading, and exchange rate for the period (1960-1970) is used to simulate the model in Chapter III. The export and import equations are solved in the following formats.

For simulation A, Equations 2.1 and 2.2 would be in the following format:

$$\log \left(\frac{IM(t) \times 100}{IM(0)}\right) = A_0 + A_1 \log \left(\frac{Y(t) \times 100}{Y(0)}\right) + A_2 \log \left(\frac{R(t)}{R(0)}\right) + U \qquad 4.1$$

$$\log \left(\frac{EX(t) \times 100}{EX(0)}\right) = B_0 + B_1 \log \left(\frac{YW(t) \times 100}{YW(0)}\right) + B_2 \log \left(\frac{R(t)}{R(0)}\right) + V \qquad 4.2$$

The variables are expressed in indexes. Each variable is divided respectively by their corresponding value of the base year.

For simulation B, the following format is used:

$$\log \left(\frac{IM(t)}{PM(t)}\right) = A_0 + A_1 \log \left(\frac{Y(t) \times 100}{Y(0)}\right) + A_2 \log \left(\frac{R(t) \times 100}{R(0)}\right) + U \qquad 4.3$$

$$\log\left(\frac{EX(t)}{PX(t)}\right) = B_0 + B_1 \log\left(\frac{YW(t) \times 100}{YW(0)}\right) + B_2 \log\left(\frac{R(t) \times 100}{R(0)}\right) + V \qquad 4.4$$

The import and export values in the above equations are each inflated respectively by corresponding import and export prices.

R(0)	= 360 Yen per Dollar (the par value)
IM(0)	= Japan's import of 1963
EX(0)	= Japan's export of 1963
Y(0)	= Japan's yearly income of 1963
YW(0)	= Yearly income of the rest of the nations in 1963
PM(t)	= Japan's import price
PX(t)	= Japan's export price

The fact that the variables have been multiplied by one hundred does not change the elasticities but only the constants. The multiplication by one hundred is to raise the magnitude of the variables.

Since there is no readily available published yearly income data of the World for the years 1960, 1961, 1962, and 1964, the yearly World income of these years is computed by dividing the yearly income of each country listed in the United Nations Statistical Yearbooks by the corresponding year's exchange rate, so as to be expressed in dollars. These incomes of various countries, except

Japan, are added together and adjusted with marginal error of +5%. The +5% discrepancy comes from the differences between the calculated world incomes, as outlined above, of 1963 and 1965, and the values reported in the United Nations Statistical Yearbook. Data for EX, IM, PX, PM, and R are obtained from various issues of United Nations Monthly Bulletin of Statistics. Data for Y and YW (except the years as mentioned above) are obtained from various issues of United Nations Statistical Yearbooks and are shown in Appendix I. All indexes have been uniformly converted to the base year of 1963.

The results of taking regression of the Equations (4.1, 4.2) and (4.3 and 4.4) have been shown in Table 2.1. The goodness of the fit which are measured by R^2 is shown in Table 4.1.

Table 4.1. R^2 for Simulation A and Simulation B.

		R_2
Simulation A		
	Imports	.989
	Exports	.984
Simulation B		
	Imports	.989
	Exports	.977

By using the elasticities and constant of Simulation A and Simulation B, the exports and imports are again generated. The results are shown in Table 4.2.

Table 4.2. Yearly exports and imports of Japan. (In billions of U.S. dollars.)

	EXPORTS			IMPORTS		
	Yearly Generated Value	Actual Value	Yearly Value of Generated Monthly Data	Yearly Generated Value	Actual Value	Yearly Value of Generated Monthly Data
<u>Simulation A</u>						
1960	4.062	4.055	4.053	4.595	4.491	4.630
1961	4.325	4.236	4.328	5.356	5.810	5.343
1962	4.994	4.916	4.977	5.913	5.637	5.990
1963	5.671	5.452	5.672	6.899	6.736	6.894
1964	6.645	6.674	6.614	7.416	7.938	7.546
1965	7.612	8.452	7.607	8.460	8.170	8.482
1966	8.816	9.776	8.819	9.582	9.523	9.572
1967	11.941	10.442	11.938	11.901	11.663	11.911
1968	13.621	12.972	13.577	13.495	12.987	13.658
1969	15.989	15.990	15.998	15.303	15.987	15.337
1970	18.393	19.318	18.383	17.727	18.881	17.763
<u>Simulation B</u>						
1960	4.212	4.055	4.351	4.698	4.491	4.564
1961	4.492	4.236	4.615	5.347	5.810	5.145
1962	4.904	4.916	5.037	5.793	5.637	5.848
1963	5.707	5.452	5.730	6.733	6.736	6.803
1964	6.382	6.674	6.581	7.423	7.938	7.550
1965	7.322	8.452	7.401	8.635	8.170	8.592
1966	8.692	9.776	8.744	9.666	9.523	9.294
1967	12.023	10.442	11.942	11.906	11.663	11.410
1968	13.162	12.972	13.457	13.415	12.987	13.486
1969	16.048	15.990	16.137	14.979	15.024	14.850
1970	19.449	19.318	19.505	18.083	18.881	18.269

The simulation for monthly exports and imports is much more complicated. Data for monthly income are not available. The monthly income data are obtained by dividing the term for the yearly income index (i.e., $\left(\frac{Y(t) \times 100}{Y(0)}\right)^{A_1}$ and not the yearly income itself by twelve. The monthly indices for PX, PM are repetitious of their quarterly indices. The remaining variables are available from the various United Nations Monthly Bulletin of Statistics. In order to be reasonably sure of the result, the monthly exports and imports are generated and compiled yearly. The results are shown in Table 4.2.

The favorable comparison of the results increases the confidence in the employment of the assumed data.

4.4 Monthly Exports and Imports

In the simulation, the open loop is first investigated. This is executed by applying the actual data of Japan's exports (Figure 4-1) and imports (Figure 4-2) into the model, developed in Chapter III, to generate the exchange rate. The closed feedback network of the model is completed by using Equations 4.1 and 4.2 in simulation A or Equations 4.3 and 4.4 in simulation B to generate exports and imports instead of their actual data. The fact that the open loop simulation gives reasonable results does not guarantee that the closed loop would behave well applies here also.

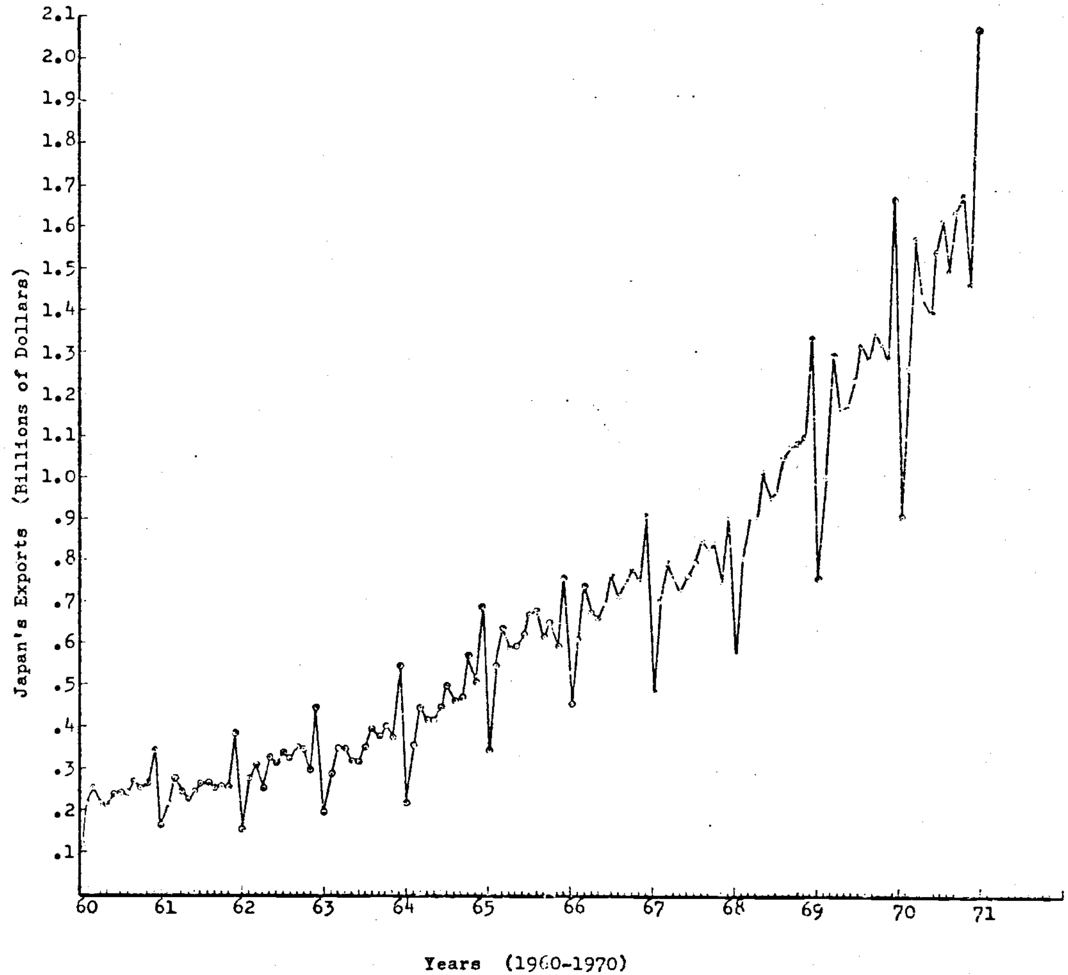

Figure 4-1. Japan's exports (1960-1970).

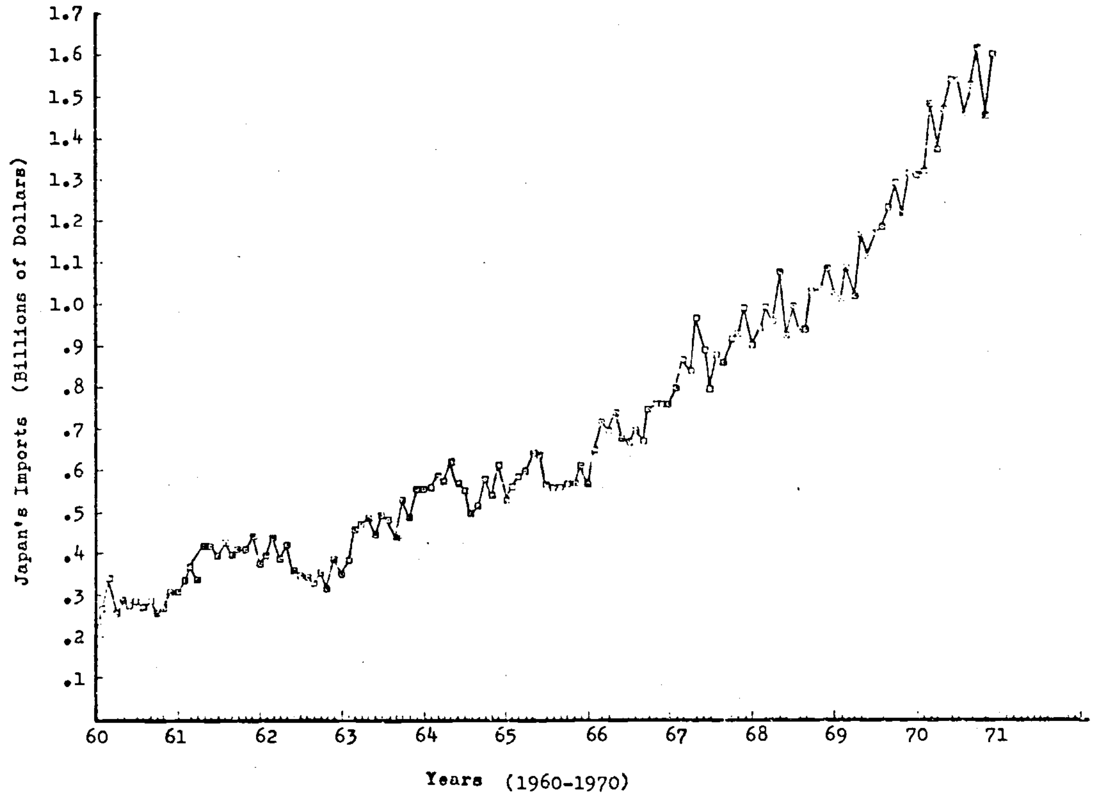

Figure 4-2. Japan's imports (1960-1970).

With the closed loop exchange rates, the monthly exports and imports are generated again. These are reported in the yearly form in Table 4. 3.

4.5 Rate of Change of Inventory Level, PHIDOT(I), $(\overset{o}{\Phi})$

To obtain PHIDOT(I), $(\overset{o}{\Phi})$, the actual data of exports and imports in Appendix I is used. The difference between these exports and imports is PHIDOT(I). For the 132 PHIDOT(I) data points calculated (1960-1970), there are forty-four positive signs (including zero difference in trade for the month June, 1970). Of these forty-four months, only four months of surplus in trade actually existed for all of the years 1961, 1962, 1963, 1964, and 1967. These indicate that the deficit of Japan in this decade have two periods. The first period, (1960-1964), Japan was 5.279 billion of U.S. dollars in deficit and the second period, (1965-1970), Japan's trade deficit was only .261 billions.

4.6 Inventory Level, PHI(I), (Φ)

The trade differences PHIDOT(I) are accumulated by applying Simpson's 3/8 rule and is labeled as PHI(I), (Φ), the market inventory level of Japan, see Figure 4-3. The inventory level, PHI(I), is a negative value all the time due to Japan's deficit in trade for

Table 4. 3. Exports and imports value of closed loop simulation (In billions of U. S. dollars).

	Exports			Imports		
	Generated Value			Generated Value		
	Simulation A	Simulation B	Actual Value	Simulation A	Simulation B	Actual Value
1960	4.053	4.359	4.055	4.630	4.564	4.491
1961	4.325	4.640	4.236	5.353	5.153	5.810
1962	4.979	5.054	4.916	5.981	5.854	5.637
1963	5.688	5.670	5.452	6.823	6.753	6.736
1964	6.643	6.444	6.674	7.424	7.505	7.938
1965	7.643	7.214	8.452	8.336	8.530	8.170
1966	8.877	8.381	9.776	9.344	9.214	9.523
1967	12.018	11.399	10.442	11.522	11.261	11.663
1968	13.632	13.027	12.972	13.454	13.362	12.987
1969	15.998	15.888	15.990	15.278	14.785	15.987
1970	18.380	19.403	19.318	17.773	18.242	18.881

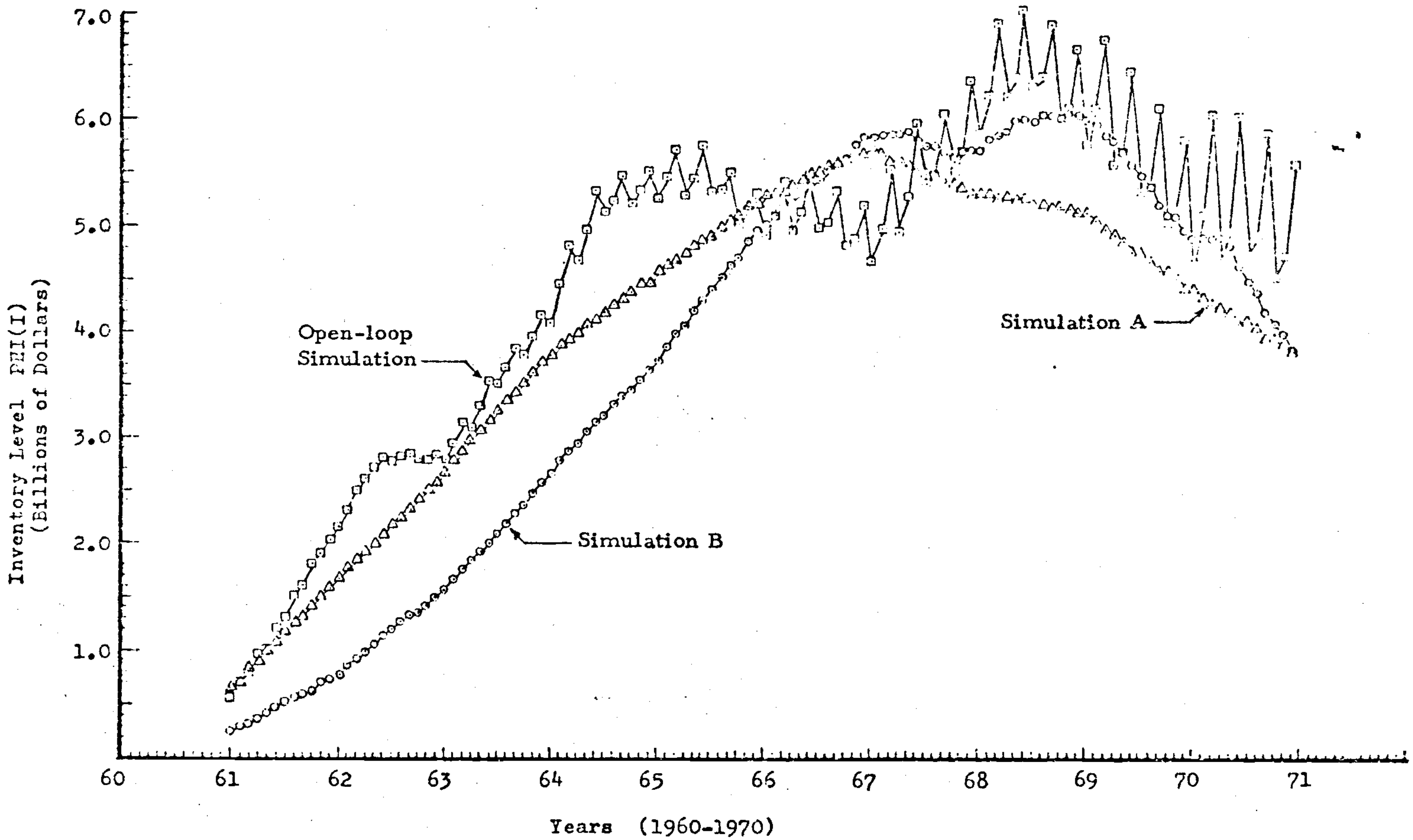

Figure 4-3. Inventory level, PHI(I), (Φ).

the decade. Simpson's 3/8 rule is applied to smooth the minor variances of PHIDOT(I).

A. Open-Loop

The inventory level of the open-loop simulation is monotonicaly increasing from 1960 to the middle of 1962. It increases till 1965, then it stays at relatively the same level for a couple of years. In 1967, it starts to increase again until the middle of 1968. Then it bounces back to the 5 billion level. The open-loop curve of PHI(I), is an indication of the actual total level of accumulated deficit of trade for the decade.

B. Closed-Loop

The result from the simulation B is closer to the open-loop simulation than the simulation A. Both curves have two extremes. The curve for simulation B is more correlated with open loop between 1968 to 1969 while PHI(I), (Φ), for simulation A stresses the heaviest deficit around 1967. Curves for simulation A and simulation B follow the general trend of the curve for open loop.

4.7 Desired Inventory Level, PHIDES(I), (Φ_d)

It is designated that the central authority's desired level of inventory PHIDES(I) (Φ_d), (see Figure 4-4), is the moving average

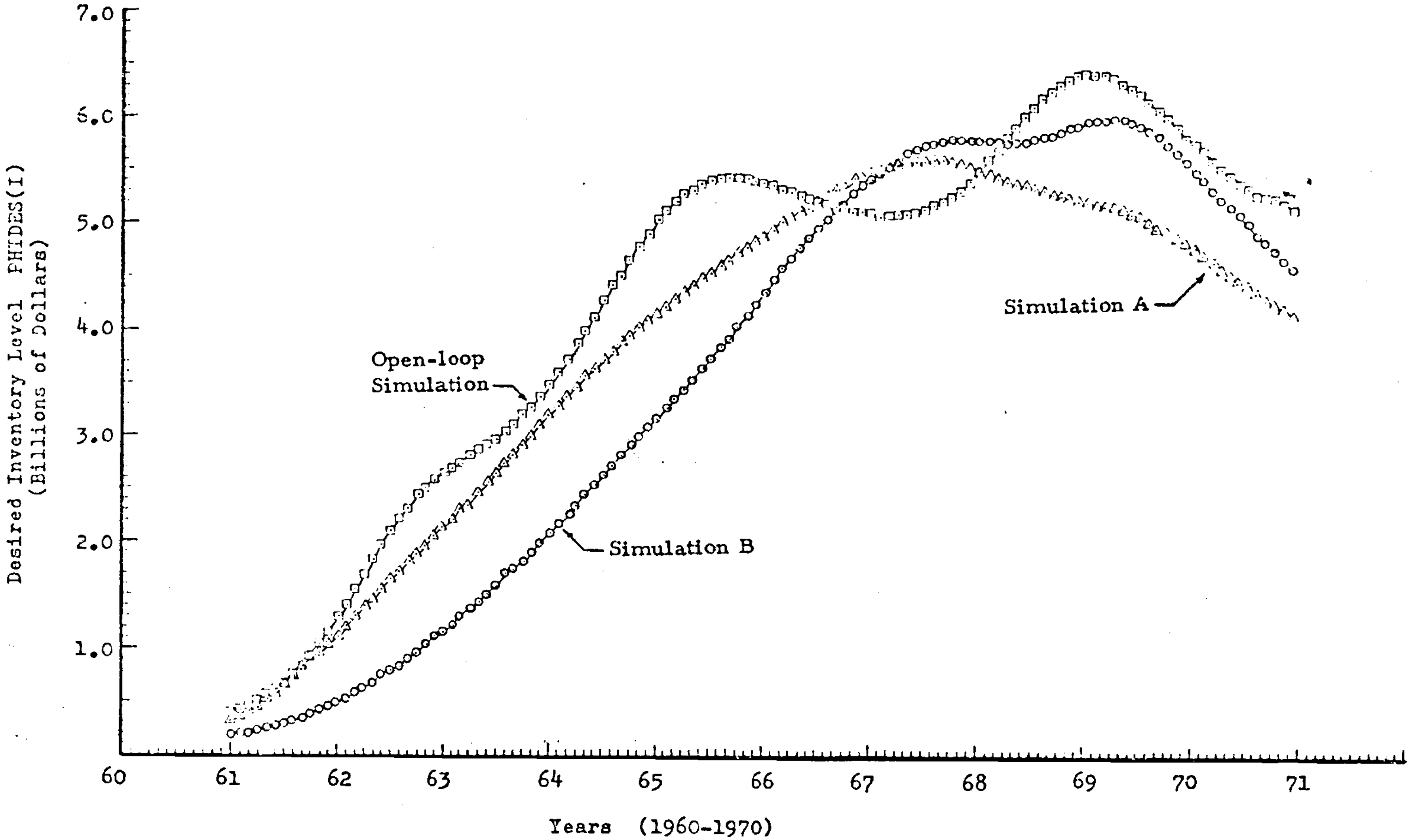

Figure 4-4. Desired inventory level, PHIDES(I), (Φ_d).

of the last twelve months of the inventory level PHI(I). This implies that PHIDES(I), (Φ_d), will always lack PHI(I) in the simulation.

A. Open-Loop

The curve for open loop simulation of PHIDES(I) is smoother than its curve in PHI(I). The maximum for PHIDES(I) has a six months delay from PHI(I).

B. Closed-Loop

Although PHIDES(I), (Φ_d) are designated as the moving average of the last twelve months of PHI(I), (Φ), the curve for the simulation B is closer to the open-loop curve than its curve in PHI(I), (Φ). Both curves for simulation A and simulation B are smoother than their corresponding curves in PHI(I), and follow the general trend of the open-loop curve of PHIDES(I).

4.8 Exchange Rates, (RDOT(I) ($\overset{o}{R}$(I)), RDIFF(I), and R(I))

The difference of the inventory level and the desired inventory, multiplied by the conversion factor of β, β being 1.6415E-10, constitutes a component of generating RDOT(I), $\overset{o}{R}$(I). The other component of RDOT(I), $\overset{o}{R}$(I), is the feedback loop of the existing exchange rate multiplied by α, α being 1.0830E-05. RDOT(I) is then accumulated to generate RDIFF(I) by the Simpson's 3/8 rule. The future exchange rate, see Figure 4-5, is the summation of the base year exchange rate (1963) plus the RDIFF(I).

A. Open-Loop

The exchange rate has been decreasing up to 1965, then it becomes more sensitive to the change in the pattern of the trade.

B. Closed-Loop

Up until 1968, the exchange rate for simulation A has a better fit. Then from 1968 to 1970, exchange rate from simulation B is by far superior. There is no upper or lower limit imposed on the exchange rate and indeed some of the worst case simulations that have been experienced do have unacceptable and uncontrollable exchange rates.

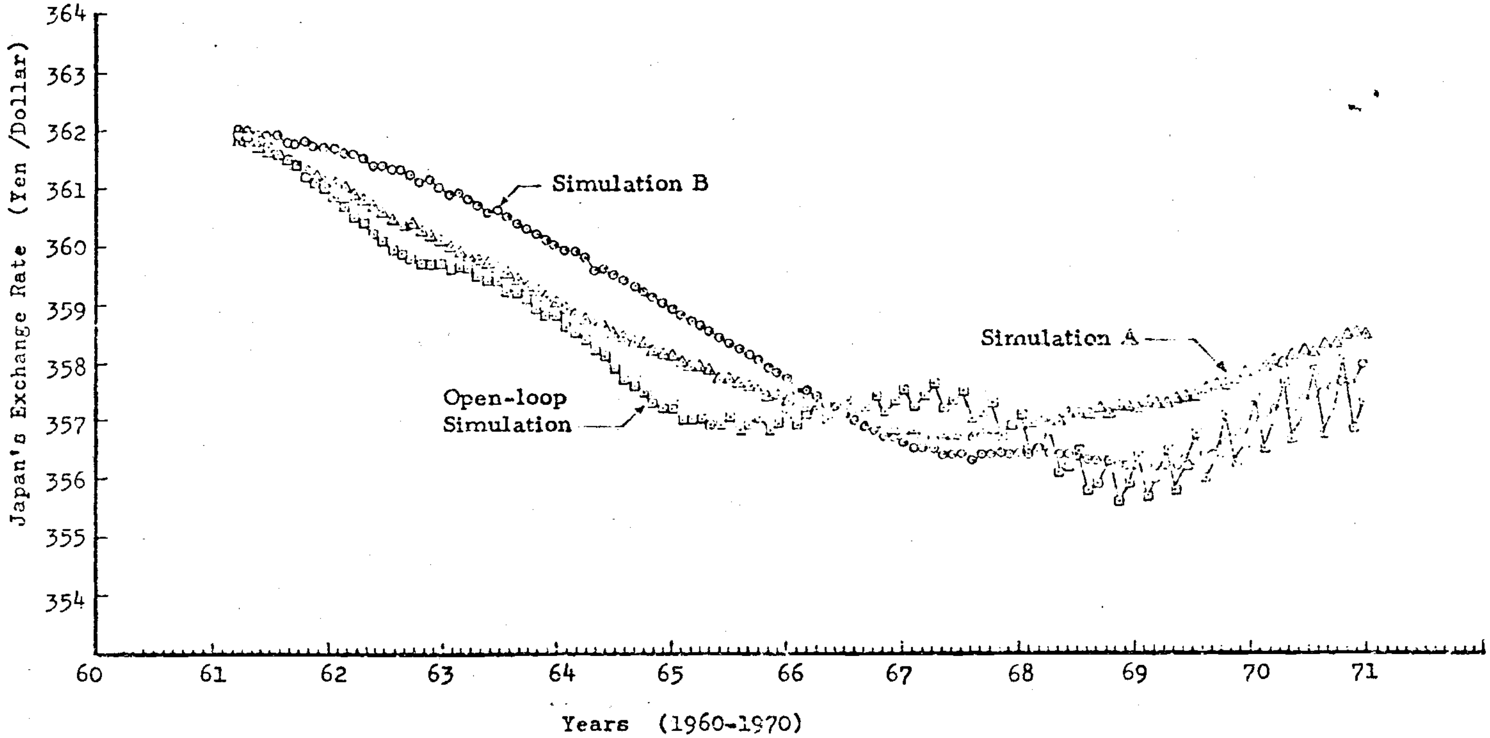

Figure 4-5. Simulated Japan's exchange rates due to trade (1960-1970).

V. CONCLUSIONS

A dynamic model of second order has been developed. The model utilized the concept of international trading and inventory control to analyze the exchange rate. The model has been built. By gathering whatever data that is available, the model was tested econometrically, then simulated on the computer. The following observations have been derived from the simulation:

1. The ratio of current exchange rate and the exchange rate at equilibrium state is introduced into the various versions of exports and imports equations. They are demonstrated and tested. The ratio does bare significance in the equations and have resemblence to the reported ratios of import prices and export prices.

2. The inventory concept PHI(I), $\underline{\Phi}$, is effectively simulated by comparing the closed-loop simulation with the open-loop simulation. The idea of desired inventory level PHIDES(I), $\underline{\Phi}_d$, is implemented as a means of control. In the simulation of both PHI(I), $\underline{\Phi}$, and PHIDES(I), $\underline{\Phi}_d$, their values are negative. This designates the country is in accumulative trade deficit. This effect, transferred to the Equation 3.2, absorbs the negative sign in front of β.

$$\overset{o}{R}(t) = -\alpha \underline{R}(t) - \beta[\underline{\Phi}_d(t)] \qquad 3.2$$

Consequently the change of exchange rate $\overset{o}{R}(t)$ becomes positive when the desired inventory level becomes bigger. This signifies that the number of Yen would go up in exchange for the dollar if the government anticipated more trade deficit than actually occurs.

3. Since in the period (1960-1970) the Yen had been pegged and defended by the Japanese authority very vigorously, see Figure 5-1, it reacts more like a step function at the beginning of the period and becomes more relaxed at the latter part of the period. The exchange rate moved from 363 Yen per dollar to 357 Yen per dollar, that is it drifted from the upper limit of the par to the lower limit of the par and was under great pressure to evaluate in the next couple of years. This corresponds to the regression of α in Equation 3.2. In this case, α has a positive sign instead of a negative sign. The negative sign is normally expected in the price structure as a corrective measure. In this case, due to the Bretton Woods system, the exchange rate supported itself within the boundaries for a certain period of time.

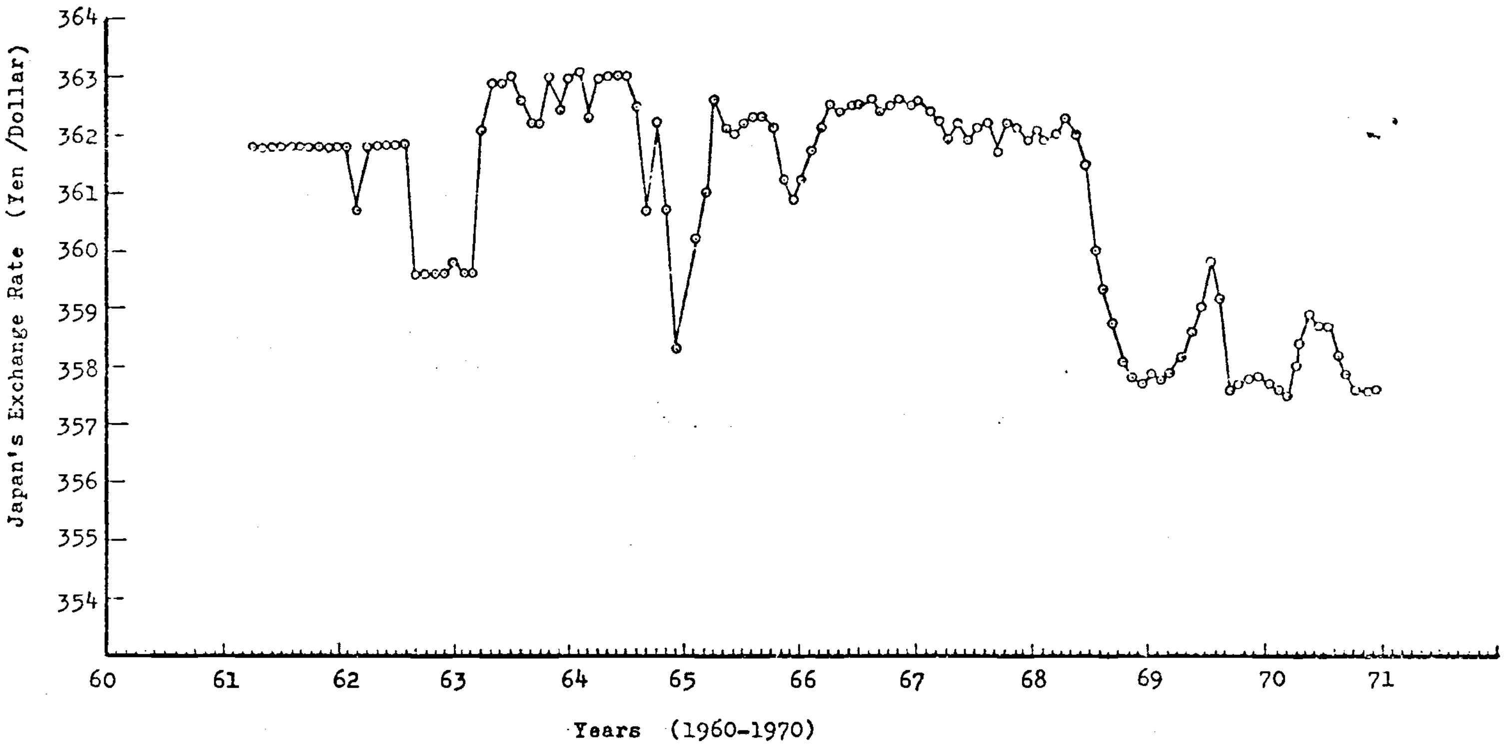

Figure 5-1. Japan's actual exchange rates (1960-1970).

Despite the fact the model is concerned with only a few effects of international trade, and in a highly simplified manner, the results of the exchange rate of the simulations (both open-loop simulation and closed-loop simulations) converged to the market exchange rate. The author does not delude himself that such a model gives a convincing picture of a pegged exchange rate system. However, under a free floating exchange rate system, as assumed in the model by disregarding pegging, the market exchange rate would fluctuate closely to the simulated results instead of quantum jumps as displayed in Figure 5-1. It should also be stressed that the main interest in this work is not building an exact model so as to draw policy conclusions based on the model. To draw policy inferences from models of any type whatsoever is a delicate and hazardous occupation. The claim of originality of this study is that it attempts to investigate the link between international trade and exchange rate via inventory control in such a manner more explicitly and more rigorously than has so far been done. The model projects, in essence, a tool, a dynamic method. It is an approximation of more realistic theories. Even so, one is hesitant to use the word approximation when one does not know that it approximates. It is hoped that through the model some insights may serve as effective ways of interpreting the "economy" in which we live.

For future studies, the following suggestions are recommended:

1. It is desirable to establish more vigorous proof, or if possible, functional relationships between purchasing power parity and exchange rates.

2. The desired inventory level PHIDES(I) can be experimented with by various schemes.

3. The speculative theory of the exchange rate should be implemented into the model.

The first suggestion is a proof in economic theory. The second suggestion is the easiest of all to accomplish. The third suggestion is difficult, if not impossible. The lack of data, the evasiveness and secretiveness of the short-term flow of capitals, and the unstructured theory, all add to the challenge of the task. Indeed, careful thoughts have to be seriously considered if one wishes to undertake the adventures.

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APPENDICES

A. Japan's imports, exports, income and world's income (yearly data).

	JAPAN			WORLD
Year	Imports	Exports	Income	Income
		(Dollars)		
1960	4491.0E 06	4055.0E 06	34.99E 09	888.547E 09*
1961	5810.0E 06	4236.0E 06	41.11E 09	922.422E 09*
1962	5637.0E 06	4916.0E 06	47.08E 09	997.057E 09*
1963	6736.0E 06	5452.0E 06	55.27E 09	1073.221E 09
1964	7938.0E 06	6674.0E 06	61.38E 09	1169.455E 09*
1965	8170.0E 06	8452.0E 06	70.64E 09	1263.862E 09
1966	9523.0E 06	9776.0E 06	81.06E 09	1373.343E 09
1967	11663.0E 06	10442.0E 06	104.89E 09	1626.012E 09
1968	12987.0E 06	12972.0E 06	124.36E 09	1744.838E 09
1969	15024.0E 06	15990.0E 06	144.06E 09	1908.236E 09
1970	18881.0E 06	19318.0E 06	171.39E 09	2063.115E 09

Data Source: United Nations Statistical Yearbook (Various Issues).

* Calculated value. See Section 4.3.

B. Price indexes and Japan's exchange rate.

	World[2]		Japan[2]		Japan's Exchange Rate[1]
	Indexes				
Year	Export Price*	Import Price*	Export Price*	Import Price*	(Yen/Dollar)
1960	100.0	101.0	106.3	102.1	358.3
1961	99.0	100.0	103.1	101.1	361.8
1962	99.0	99.0	101.0	98.9	358.2
1963	100.0	100.0	100.0	100.0	362.0
1964	102.0	102.1	99.0	102.1	359.3
1965	103.0	103.1	96.9	105.3	360.9
1966	105.0	104.0	98.0	105.0	362.5
1967	105.0	104.0	101.0	105.0	361.9
1968	104.0	103.0	101.0	104.0	357.7
1969	107.0	106.0	105.0	103.0	357.8
1970	113.0	111.0	111.0	108.0	357.6

[1] Data Source: United Nations Statistical Yearbook (Various Issues).
[2] Data Source: United Nations Monthly Bulletin of Statistics (Various Issues).
* 1963 = 100

C. Japan's monthly imports and exports (in dollars).

	Exports	Imports
1960 JANUARY	218.0E 06	331.0E 06
1960 FEBRUARY	318.0E 06	364.0E 06
1960 MARCH	350.0E 06	435.0E 06
1960 APRIL	311.0E 06	355.0E 06
1960 MAY	311.0E 06	385.0E 06
1960 JUNE	337.0E 06	372.0E 06
1960 JULY	340.0E 06	380.0E 06
1960 AUGUST	342.0E 06	368.0E 06
1960 SEPTEMBER	368.0E 06	384.0E 06
1960 OCTOBER	353.0E 06	352.0E 06
1960 NOVEMBER	366.0E 06	364.0E 06
1960 DECEMBER	443.0E 06	403.0E 06
1961 JANUARY	261.0E 06	403.0E 06
1961 FEBRUARY	315.0E 06	433.0E 06
1961 MARCH	371.0E 06	463.0E 06
1961 APRIL	346.0E 06	439.0E 06
1961 MAY	328.0E 06	513.0E 06
1961 JUNE	341.0E 06	510.0E 06
1961 JULY	363.0E 06	491.0E 06
1961 AUGUST	362.0E 06	521.0E 06
1961 SEPTEMBER	355.0E 06	494.0E 06
1961 OCTOBER	354.0E 06	503.0E 06
1961 NOVEMBER	358.0E 06	504.0E 06
1961 DECEMBER	481.0E 06	539.0E 06
1962 JANUARY	252.0E 06	473.0E 06
1962 FEBRUARY	374.0E 06	491.0E 06
1962 MARCH	407.0E 06	533.0E 06
1962 APRIL	354.0E 06	462.0E 06
1962 MAY	426.0E 06	518.0E 06
1962 JUNE	410.0E 06	458.0E 06
1962 JULY	438.0E 06	446.0E 06
1962 AUGUST	423.0E 06	440.0E 06
1962 SEPTEMBER	450.0E 06	428.0E 06
1962 OCTOBER	442.0E 06	450.0E 06
1962 NOVEMBER	398.0E 06	411.0E 06
1962 DECEMBER	543.0E 06	486.0E 06
1963 JANUARY	292.0E 06	450.0E 06
1963 FEBRUARY	387.0E 06	480.0E 06
1963 MARCH	447.0E 06	552.0E 06
1963 APRIL	445.0E 06	569.0E 06
1963 MAY	413.0E 06	583.0E 06
1963 JUNE	432.0E 06	541.0E 06
1963 JULY	449.0E 06	585.0E 06
1963 AUGUST	493.0E 06	579.0E 06
1963 SEPTEMBER	477.0E 06	535.0E 06
1963 OCTOBER	501.0E 06	627.0E 06
1963 NOVEMBER	471.0E 06	586.0E 06
1963 DECEMBER	642.0E 06	651.0E 06
1964 JANUARY	313.0E 06	652.0E 06
1964 FEBRUARY	457.0E 06	656.0E 06
1964 MARCH	544.0E 06	685.0E 06
1964 APRIL	514.0E 06	675.0E 06
1964 MAY	514.0E 06	719.0E 06
1964 JUNE	545.0E 06	668.0E 06
1964 JULY	598.0E 06	650.0E 06
1964 AUGUST	562.0E 06	594.0E 06

1964 SEPTEMBER	570.0E 06	615.0E 06
1964 OCTOBER	668.0E 06	680.0E 06
1964 NOVEMBER	609.0E 06	640.0E 06
1964 DECEMBER	789.0E 06	710.0E 06
1965 JANUARY	444.0E 06	629.0E 06
1965 FEBRUARY	645.0E 06	660.0E 06
1965 MARCH	735.0E 06	688.0E 06
1965 APRIL	686.0E 06	698.0E 06
1965 MAY	694.0E 06	739.0E 06
1965 JUNE	719.0E 06	733.0E 06
1965 JULY	756.0E 06	666.0E 06
1965 AUGUST	767.0E 06	659.0E 06
1965 SEPTEMBER	711.0E 06	659.0E 06
1965 OCTOBER	748.0E 06	666.0E 06
1965 NOVEMBER	696.0E 06	667.0E 06
1965 DECEMBER	855.0E 06	706.0E 06
1966 JANUARY	5.5800E 08	6.6700E 08
1966 FEBRUARY	7.0500E 08	7.4700E 08
1966 MARCH	8.3400E 08	8.1100E 08
1966 APRIL	7.7700E 08	7.9500E 08
1966 MAY	7.6300E 08	8.3700E 08
1966 JUNE	7.9800E 08	7.7600E 08
1966 JULY	8.6500E 08	7.6500E 08
1966 AUGUST	8.1400E 08	7.9500E 08
1966 SEPTEMBER	8.4500E 08	7.7000E 08
1966 OCTOBER	8.7900E 08	8.4300E 08
1966 NOVEMBER	8.5000E 08	8.5700E 08
1966 DECEMBER	1.0910E 09	8.5700E 08
1967 JANUARY	5.8100E 08	8.5900E 08
1967 FEBRUARY	8.0500E 08	8.9400E 08
1967 MARCH	8.9500E 08	9.6100E 08
1967 APRIL	8.5500E 08	9.3500E 08
1967 MAY	8.2500E 08	1.0660E 09
1967 JUNE	8.6300E 08	9.8800E 08
1967 JULY	8.9900E 08	8.9600E 08
1967 AUGUST	9.4300E 08	9.7800E 08
1967 SEPTEMBER	9.2200E 08	9.5900E 08
1967 OCTOBER	9.4600E 08	1.0140E 09
1967 NOVEMBER	8.4900E 08	1.0280E 09
1967 DECEMBER	1.0590E 09	1.0880E 09
1968 JANUARY	6.6100E 08	1.0070E 09
1968 FEBRUARY	9.0300E 08	1.0410E 09
1968 MARCH	1.0480E 09	1.0920E 09
1968 APRIL	1.0060E 09	1.0570E 09
1968 MAY	1.1130E 09	1.1760E 09
1968 JUNE	1.0520E 09	1.0220E 09
1968 JULY	1.0700E 09	1.0960E 09
1968 AUGUST	1.1460E 09	1.0340E 09
1968 SEPTEMBER	1.1730E 09	1.0390E 09
1968 OCTOBER	1.1810E 09	1.1270E 09
1968 NOVEMBER	1.1970E 09	1.1360E 09
1968 DECEMBER	1.4300E 09	1.1830E 09
1969 JANUARY	8.5900E 08	1.1220E 09
1969 FEBRUARY	1.1000E 09	1.1110E 09
1969 MARCH	1.3950E 09	1.1890E 09
1969 APRIL	1.2660E 09	1.1190E 09

1969 MAY	1.2750E 09	1.2630E 09
1969 JUNE	1.3360E 09	1.2180E 09
1969 JULY	1.4190E 09	1.2710E 09
1969 AUGUST	1.3830E 09	1.2830E 09
1969 SEPTEMBER	1.4450E 09	1.3290E 09
1969 OCTOBER	1.4230E 09	1.3920E 09
1969 NOVEMBER	1.3820E 09	1.3150E 09
1969 DECEMBER	1.7650E 09	1.4120E 09
1970 JANUARY	1.0930E 09	1.4050E 09
1970 FEBRUARY	1.3660E 09	1.4150E 09
1970 MARCH	1.6720E 09	1.5830E 09
1970 APRIL	1.5330E 09	1.4750E 09
1970 MAY	1.4960E 09	1.5650E 09
1970 JUNE	1.6400E 09	1.6400E 09
1970 JULY	1.7120E 09	1.6460E 09
1970 AUGUST	1.5950E 09	1.5550E 09
1970 SEPTEMBER	1.7350E 09	1.6290E 09
1970 OCTOBER	1.7750E 09	1.7140E 09
1970 NOVEMBER	1.5600E 09	1.5530E 09
1970 DECEMBER	2.1680E 09	1.7020E 09
1971 JANUARY	1.2580E 09	1.5790E 09
1971 FEBRUARY	1.6540E 09	1.5680E 09
1971 MARCH	2.1430E 09	1.7200E 09
1971 APRIL	1,8990E 09	1.6550E 09
1971 MAY	1.9190E 09	1.6510E 09
1971 JUNE	2.0480E 09	1.6590E 09
1971 JULY	2.1680E 09	1.6680E 09
1971 AUGUST	2.0780E 09	1.4840E 09
1971 SEPTEMBER	2.1090E 09	1.5120E 09
1971 OCTOBER	2.1190E 09	1.6960E 09
1971 NOVEMBER	2.0690E 09	1.7200E 09
1971 DECEMBER	2.6220E 09	1.7550E 09

Data source: United Nations Monthly Bulletin of Statistics (various issues).

D. Japan's import and export price indexes[1] and exchange rates[2] (Monthly data).

	Export Price Index	Import Price Index	Exchange Rate (Yen/Dollar)
1960 JANUARY	106.4	101.6	360.0
1960 FEBRUARY	107.5	102.8	360.0
1960 MARCH	107.5	104.0	360.0
1960 APRIL	106.4	102.8	360.0
1960 MAY	107.5	100.4	360.0
1960 JUNE	109.7	100.4	360.0
1960 JULY	109.7	99.2	359.6
1960 AUGUST	109.7	96.8	359.6
1960 SEPTEMBER	109.7	96.8	359.6
1960 OCTOBER	109.7	98.0	359.6
1960 NOVEMBER	107.5	95.6	361.5
1960 DECEMBER	108.6	87.3	359.6
1961 JANUARY	105.3	96.8	359.6
1961 FEBRUARY	108.6	96.8	359.6
1961 MARCH	105.3	98.0	359.6
1961 APRIL	106.4	96.8	361.8
1961 MAY	105.3	98.0	361.8
1961 JUNE	106.4	98.0	361.8
1961 JULY	105.3	96.8	361.8
1961 AUGUST	108.6	96.8	361.8
1961 SEPTEMBER	106.4	98.0	361.8
1961 OCTOBER	105.3	96.8	361.8
1961 NOVEMBER	106.4	99.2	361.8
1961 DECEMBER	107.5	96.8	361.8
1962 JANUARY	102.1	101.1	361.8
1962 FEBRUARY	102.1	101.1	361.8
1962 MARCH	103.1	101.1	360.7
1962 APRIL	102.1	100.0	361.8
1962 MAY	102.1	100.0	361.8
1962 JUNE	102.1	100.0	361.8
1962 JULY	100.0	98.9	361.8
1962 AUGUST	102.1	98.9	361.8
1962 SEPTEMBER	100.0	96.8	359.6
1962 OCTOBER	101.0	96.8	359.6
1962 NOVEMBER	100.0	97.9	359.6
1962 DECEMBER	100.0	97.9	359.6
1963 JANUARY	99.0	97.9	359.8
1963 FEBRUARY	100.0	100.0	359.6
1963 MARCH	101.0	101.1	359.6
1963 APRIL	101.0	101.1	362.1
1963 MAY	102.1	100.0	362.9
1963 JUNE	102.1	100.0	362.9
1963 JULY	102.1	102.1	363.0
1963 AUGUST	97.9	101.1	362.6
1963 SEPTEMBER	100.0	98.9	362.2
1963 OCTOBER	100.0	101.1	362.2
1963 NOVEMBER	101.0	101.1	363.0
1963 DECEMBER	100.0	103.2	362.4
1964 JANUARY	99.0	104.3	363.0
1964 FEBRUARY	99.0	103.2	363.1
1964 MARCH	99.0	104.3	362.3
1964 APRIL	97.9	104.3	363.0
1964 MAY	100.0	103.2	363.0
1964 JUNE	99.0	103.2	363.0
1964 JULY	99.0	103.2	363.0
1964 AUGUST	100.0	100.0	362.5

1964 SEPTEMBER	99.0	102.1	360.7
1964 OCTOBER	100.0	101.1	362.2
1964 NOVEMBER	97.9	103.2	360.7
1964 DECEMBER	97.9	103.2	358.3
1965 JANUARY	97.9	104.3	358.9
1965 FEBRUARY	97.9	105.3	360.2
1965 MARCH	97.9	106.4	361.0
1965 APRIL	95.8	104.3	362.6
1965 MAY	96.9	105.3	362.1
1965 JUNE	96.9	104.3	362.0
1965 JULY	97.9	105.3	362.2
1965 AUGUST	97.9	104.3	362.3
1965 SEPTEMBER	97.9	104.3	362.3
1965 OCTOBER	97.9	104.3	362.1
1965 NOVEMBER	97.9	104.3	361.2
1965 DECEMBER	96.9	103.2	360.9
1966 JANUARY	98.0	101.0	361.2
1966 FEBRUARY	99.0	101.0	361.7
1966 MARCH	98.0	102.0	362.1
1966 APRIL	99.0	103.0	362.5
1966 MAY	101.0	102.0	362.4
1966 JUNE	99.0	102.0	362.5
1966 JULY	99.0	102.0	362.5
1966 AUGUST	99.0	101.0	362.6
1966 SEPTEMBER	99.0	100.0	362.4
1966 OCTOBER	99.0	100.0	362.5
1966 NOVEMBER	96.0	101.0	362.6
1966 DECEMBER	99.0	101.0	362.5
1967 JANUARY	99.0	101.0	362.6
1967 FEBRUARY	98.0	101.0	362.4
1967 MARCH	99.0	102.0	362.2
1967 APRIL	99.0	102.0	361.9
1967 MAY	102.0	100.0	362.0
1967 JUNE	102.0	99.0	361.9
1967 JULY	101.0	99.0	362.1
1967 AUGUST	101.0	98.0	362.2
1967 SEPTEMBER	102.0	100.0	361.7
1967 OCTOBER	100.0	101.0	362.0
1967 NOVEMBER	99.0	102.0	362.1
1967 DECEMBER	100.0	102.0	361.9
1968 JANUARY	99.0	106.0	362.1
1968 FEBRUARY	100.0	105.0	361.9
1968 MARCH	100.0	106.0	362.0
1968 APRIL	100.0	106.0	362.3
1968 MAY	101.0	105.0	362.0
1968 JUNE	101.0	104.0	361.5
1968 JULY	102.0	104.0	360.0
1968 AUGUST	103.0	103.0	359.4
1968 SEPTEMBER	101.0	103.0	358.8
1968 OCTOBER	103.0	102.0	358.1
1968 NOVEMBER	101.0	102.0	357.8
1968 DECEMBER	102.0	101.0	357.7
1969 JANUARY	103.0	102.0	357.9
1969 FEBRUARY	104.0	102.0	357.8
1969 MARCH	101.0	102.0	357.9
1969 APRIL	104.0	99.0	358.2

1969 MAY	106.0	101.0	358.6
1969 JUNE	105.0	100.0	359.0
1969 JULY	105.0	101.0	359.8
1969 AUGUST	107.0	99.0	359.2
1969 SEPTEMBER	107.0	102.0	357.6
1969 OCTOBER	106.0	104.0	357.7
1969 NOVEMBER	106.0	106.0	357.8
1969 DECEMBER	108.0	106.0	357.8
1970 JANUARY	108.0	107.0	357.7
1970 FEBRUARY	105.0	112.0	357.6
1970 MARCH	106.0	112.0	357.5
1970 APRIL	107.0	108.0	358.4
1970 MAY	114.0	108.0	358.9
1970 JUNE	112.0	107.0	358.7
1970 JULY	113.0	108.0	358.7
1970 AUGUST	115.0	110.0	358.2
1970 SEPTEMBER	114.0	110.0	357.9
1970 OCTOBER	112.0	108.0	357.6
1970 NOVEMBER	113.0	109.0	357.6
1970 DECEMBER	112.0	109.0	357.6

[1] Data source: United Nations Monthly Bulletin of Statistics (various issues)

[2] Data source: International Monetary Fund International Financial Statistics (various issues).

APPENDIX II

Regression analysis are done by *SIPS (Statistical Interactive Programming System), a library program, on the Computer CDC 3300 located at Oregon State University.

A. Fortran program for generating data for elasticities for Simulation A.

```
      PROGRAM PREPARE
      DIMENSION X(40),TM(40),Y(40),TY(40)
      DIMENSION PX(40),PXW(40),PM(40),PMW(40),R(40)
      DIMENSION GOLTY(40),RDIFF(40)
      DIMENSION GOLX(40),GOLTM(40),GOLY(40),PIX(40),PIM(40)
      DO 10 I=1,11
      READ (10,101)TM(I),X(I),TY(I),Y(I)
      READ (15,102) PXW(I),PX(I),PMW(I),PM(I),R(I)
      GOLX(I)=ALOG10(X(I)/5452.0E 06*100.0)
      RDIFF(I)=ALOG10(R(I)/360.0)
      GOLTM(I)=ALOG10(TM(I)/6736.0E 06*100.0)
      GOLY(I)=ALOG10(Y(I)/55.27E 09*100.0)
      GOLTY(I)=ALOG10(TY(I)/1073.221E 09*100.0)
      PIX(I)=ALOG10(PX(I)/PXW(I))
      PIM(I)=ALOG10(PM(I)/PMW(I))
      WRITE(20,201) GOLX(I),PIX(I),GOLTY(I),RDIFF(I)
      WRITE(21,202) GOLTM(I),PIM(I),GOLY(I),RDIFF(I)
      WRITE (22,203) GOLX(I),GOLTY(I),RDIFF(I)
      WRITE (23,204) GOLTM(I),GOLY(I),RDIFF(I)
10    CONTINUE
101   FORMAT (4X,E11.1,3X,E11.1,3X,E12.1,6X,E10.0)
102   FORMAT (3X,5(XF5.0))
201   FORMAT (4(2XE15.7))
202   FORMAT (4(2XE15.7))
203   FORMAT (3(2XE15.7))
204   FORMAT (3(2XE15.7))
      END
```

B. Fortran program for generating data for elasticities for Simulation B.

```
      PROGRAM PREPARE
      DIMENSION X(40),TM(40),Y(40),TY(40)
      DIMENSION PX(40),PXW(40),PM(40),PMW(40),R(40)
      DIMENSION GOLTY(40),RDIFF(40)
      DIMENSION GOLX(40),GOLTM(40),GOLY(40),PIX(40),PIM(40)
      DO 10 I=1,11
      READ (10,101)TM(I),X(I),TY(I),Y(I)
      READ (15,102) PXW(I),PX(I),PMW(I),PM(I),R(I)
      GOLX(I)=ALOG10(X(I)/PX(I))
      RDIFF(I)=ALOG10(R(I)/360.0*100.0)
      GOLTM(I)=ALOG10(TM(I)/PM(I))
      GOLY(I)=ALOG10(Y(I)/55.27E 09*100.0)
      GOLTY(I)=ALOG10(TY(I)/1073.221E 09*100.0)
      PIX(I)=ALOG10(PX(I)/PXW(I)*100.0)
      PIM(I)=ALOG10(PM(I)/PMW(I)*100.0)
      WRITE(20,201) GOLX(I),PIX(I),GOLTY(I),RDIFF(I)
      WRITE(21,202) GOLTM(I),PIM(I),GOLY(I),RDIFF(I)
      WRITE (22,203) GOLX(I),GOLTY(I),RDIFF(I)
      WRITE (23,204) GOLTM(I),GOLY(I),RDIFF(I)
10    CONTINUE
101   FORMAT (4X,E11.1,3X,E11.1,3X,E12.1,6X,E10.0)
102   FORMAT (3X,5(XF5.0))
201   FORMAT (4(2XE15.7))
202   FORMAT (4(2XE15.7))
203   FORMAT (3(2XE15.7))
204   FORMAT (3(2XE15.7))
      END
```

C. Fortran program for generating Japan's yearly exports and imports for Simulation A.

```
      PROGRAM TEST
      DIMENSION X(100),TM(100)
      DIMENSION EX(100),TIM(100)
      DIMENSION Y(100),TY(100)
      DIMENSION FX(100),PXW(100),PM(100),PMW(100),R(100)
      DO 20 I=1,11
      READ (10,101) TIM(I),EX(I),TY(I),Y(I)
  101 FORMAT (4X,E11.1,3X,E11.1,3X,E12.1,6X,E10.0)
  102 FORMAT (3X,5(XF5.0))
      READ (15,102) PXW(I),FX(I),PMW(I),PM(I),R(I)
      A=0.027139
      B=2.107798
      X(I)=A*(TY(I)/1073.221E 09*100.0)**1.7919*(R(I)/360.0
     1 )**(-0.44905)*5452.0E 06/100.0
      TM(I)=B*(Y(I)/55.27E 09*100.0)**0.55183*(R(I)/360.0)
     1**1.5576*6739.0E 06/100.0
      WRITE (20,103)I,X(I),I,EX(I),I,TM(I),I,TIM(I)
  103 FORMAT (≠ X(≠,I2,≠)=≠,E13.7,2X,≠EX(≠,I2,≠)=≠,E13.7,2X,≠TM(≠,I2,
     1≠)=≠,E13.7,2X,≠TIM(≠,I2,≠)=≠,E13.7)
   20 CONTINUE
      END
```

D. Fortran program for generating Japan's yearly exports and imports for Simulation B.

```
      PROGRAM TEST
      DIMENSION X(100),TM(100)
      DIMENSION EX(100),TIM(100)
      DIMENSION Y(100),TY(100)
      DIMENSION PX(100),PXW(100),PM(100),PMW(100),R(100)
      DO 20 I=1,11
      READ (10,101) TIM(I),EX(I),TY(I),Y(I)
  101 FORMAT (4X,E11.1,3X,E11.1,3X,E12.1,6X,E10.0)
  102 FORMAT (3X,5(XF5.0))
      READ (15,102) PXW(I),PX(I),PMW(I),PM(I),R(I)
      A=0.0201326
      B=34197.3442
      X(I)=(A*(TY(I)/1073.221E 09*100.0)**1.7716*(R(I)/360.0*
     1100.0)**2.9511)*PX(I)
      TM(I)=(B*(Y(I)/55.27E 09*100.0)**(0.31396)*(R(I)/360.0*
     1100.0)**0.83212)*PM(I)
      WRITE (20,103)I,X(I),I,EX(I),I,TM(I),I,TIM(I)
  103 FORMAT (≠ X(≠,I2,≠)=≠,E13.7,2X,≠EX(≠,I2,≠)=≠,E13.7,2X,≠TM(≠,I2,
     1≠)=≠,E13.7,2X,≠TIM(≠,I2,≠)=≠,E13.7)
   20 CONTINUE
      END
```

E. Fortran program for generating Japan's monthly exports and imports for Simulation A.

```
      PROGRAM TEST
      DIMENSION X(100),TM(100)
      DIMENSION EX(100),TIM(100)
      DIMENSION Y(100),TY(100)
      DIMENSION PX(100),PXW(100),PM(100),PMW(100),R(100)
      DO 20 I=1,132
      READ (10,101) EX(I),TIM(I)
  101 FORMAT (5X,F10.1,10X,F10.1)
      READ (11,102) PX(I),PM(I),R(I)
  102 FORMAT (3(XF5.0))
      READ (13,105) Y(I),TY(I)
  105 FORMAT (5X,F12.0,3X,F13.0)
      A=0.027189
      B=2.307798
      TTY=(TY(I)/1073.221E 09*100.0)**1.7919/12.0
      YY=(Y(I)/55.27E 09*100.0)**0.85183/12.0
      X(I)=A*TTY*(R(I)/360.0)**(-0.44905)*5452.0E 06/100.0
      TM(I)=B*YY*(R(I)/360.0)**(1.6576)*6735.0E 06/100.0
      WRITE (20,103)I,X(I),I,EX(I),I,TM(I),I,TIM(I),I,R(I)
  103 FORMAT (≠ X(≠,I2,≠)=≠,E13.7,2X,≠EX(≠,I2,≠)=≠,E13.7,2X,≠TM(≠,I2,
     1≠)=≠,E13.7,2X,≠TIM(≠,I2,≠)=≠,E13.7,2X,≠R(≠,I2,≠)=≠,F5.1)
   20 CONTINUE
      END
```

F. Fortran program for generating Japan's monthly exports and imports for Simulation B.

```
      PROGRAM TEST
      DIMENSION X(100),TM(100)
      DIMENSION EX(100),TIM(100)
      DIMENSION Y(100),TY(100)
      DIMENSION PX(100),PXW(100),PM(100),PMW(100),R(100)
      DO 20 I=1,132
      READ (10,101) EX(I),TIM(I)
  101 FORMAT (5X,F10.1,10X,F10.1)
      READ (11,102) PX(I),PM(I),R(I)
  102 FORMAT (3(XF5.0))
      READ (13,105) Y(I),TY(I)
  105 FORMAT (5X,F12.0,9X,F13.0)
      A=0.0201326
      B=34197.9442
      TTY=(TY(I)/1073.221E 09*100.0)**1.7716/12.0
      YY=(Y(I)/55.27E 09*100.0)**0.81398/12.0
      X(I)=(A*TTY*(R(I)/360.0*100.0)**2.9511)*PX(I)
      TM(I)=(B*YY*(R(I)/360.0*100.0)**0.83212)*PM(I)
      WRITE (20,103)I,X(I),I,EX(I),I,TM(I),I,TIM(I),I,R(I)
  103 FORMAT (≠ X(≠,I2,≠)=≠,E13.7,2X,≠EX(≠,I2,≠)=≠,E13.7,2X,≠TM(≠,I2,
     1≠)=≠,E13.7,2X,≠TIM(≠,I2,≠)=≠,E13.7,2X,≠R(≠,I2,≠)=≠,F5.1)
   20 CONTINUE
      END
```

G. Fortran program for generating data for α and β.

```
      PROGRAM INTER
      DIMENSION X(200),Y(200),R(200),PHIDOT(200),PHI(200)
      DIMENSION PX(200),PM(200)
      DIMENSION PHIDLS(200),BETA(200),RDOT(200)
      DIMENSION DOTPHI(200),DIFFPHI(200)
      DO 20 I=2,133
      READ (10,101) X(I),Y(I)
      READ (11,301) PX(I),PM(I),R(I)
301   FORMAT (3(XF5.0))
 20   CONTINUE
      PHI(1)=0.0
      DO 30 I=2,133
      PHIDOT(I)=X(I)-Y(I)
      N3=0
      N1=I/3
      N2=I-3*N1+1
      I5=I-2
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      IF (I-7) 55,56,56
 55   GO TO (92,92,93,94,95,96) I
 56   N3=I-4
      GO TO (82,60,71)N2
 60   DO 61 I5=2,N3,3
      SUM1=SUM1+PHIDOT(I5)+PHIDOT(I5+1)
      SUM2 =SUM2+PHIDOT(I5+2)
 61   CONTINUE
      I5=2
      GO TO 90
 71   SUM3=PHIDOT(2)
      DO 72 I5=3,N3,3
      SUM1=SUM1+PHIDOT(I5)+PHIDOT(I5+1)
      SUM2=SUM2+PHIDOT(I5+2)
 72   CONTINUE
      I5=3
      GO TO 90
 82   SUM3=PHIDOT(2)
      SUM3=(PHIDOT(2)+PHIDOT(3))/2.+SUM3
      DO 81 I5=4,N3,3
      SUM1=SUM1+PHIDOT(I5)+PHIDOT(I5+1)
      SUM2=SUM2+PHIDOT(I5+2)
 81   CONTINUE
      I5=4
      GO TO 90
```

```
 92 PHI(I)=PHIDOT(2)
    GO TO 99
 93 PHI(I)=PHIDOT(2)+(PHIDOT(2)+PHIDOT(3))/2.
    GO TO 99
 95 SUM3=PHIDOT(1)
    GO TO 94
 96 SUM3=PHIDOT(2)
    SUM3=SUM3+(PHIDOT(2)+PHIDOT(3))/2.
 94 SUM1=3.*(PHIDOT(I5)+PHIDOT(I5+1))
    GO TO 98
 90 SUM1=3.*(SUM1+PHIDOT(N3+2)+PHIDOT(N3+3))
    SUM2=2.*SUM2
 98 PHI(I)=3./8.*(PHIDOT(I5-1)+PHIDOT(I)+SUM1+SUM2)+SUM3
 99 CONTINUE
 30 CONTINUE
    I1=2
    DOTPHI(13)=0.0
    DO 41 J=13,133
    N=0
    PHIDESR =0.0
    DO 40 I=I1,133
    PHIDESR =PHIDESR +PHI(I)
    N=N+1
    IF (N-11) 40,40,42
 40 CONTINUE
 42 PHIDES (J)=PHIDESR/12.
    I1=I1+1
 41 CONTINUE
    DO 31 I=13,133
    DOTPHI(I)=PHI(I)-PHIDES(I)
    ROOT(I)=R(I)-R(I-1)
    WRITE (20,102) I,X(I),I,Y(I),I,PHIDOT(I)
102 FORMAT (X,≠X(≠,I3,≠)=≠,E14.7,2X,≠Y(≠,I3,≠)=≠,E14.7,
   12X,≠PHIDOT(≠,I3,≠)=≠,E14.7)
    WRITE (21,103) I,PHI(I),I,PHIDES(I),I,DOTPHI(I)
103 FORMAT (X,≠PHI(≠,I3,≠)=≠,E14.7,2X,≠PHIDES(≠,I3,≠)=≠,
   1E14.7,2X,≠DOTPHI(≠,I3,≠)=≠,E14.7)
    WRITE (22,104) ROOT(I),R(I),DOTPHI(I)
104 FORMAT (3(2XE14.7))
    WRITE (23,105) I,ROOT(I),I,R(I)
105 FORMAT (X,≠ROOT(≠,I3,≠)=≠,F5.1,2X,≠R(≠,I3,≠)=≠,F5.1)
    DUMMY=1.0E-10
    DIFFPHI(I)=DOTPHI(I)*DUMMY
    WRITE (24,104) ROOT(I),R(I),DIFFPHI(I)
 31 CONTINUE
101 FORMAT (5X,F10.1,10X,F10.1)
    END
```

H. Fortran program for closed-loop Simulation A.

```
      PROGRAM MAIN
      DIMENSION X(200),TM(200),Y(200),TY(200)
      DIMENSION R(200),RDIFF(200),ROUT(200),RR(200)
      DIMENSION PHI(200),PHIDOT(200),DOTPHI(200)
      DIMENSION PHIDES(200)
      DIMENSION PX(200),PXH(200),PM(200),PMH(200)
      DIMENSION EX(200),TIM(200)
      COMMON PHI(200),PHIDOT(200)
      COMMON /RDIFFJ/ RDIFF(200),RDOT(200)
      PHI(1)=0.0
      QM=12.0
      NM=133
      DO 301 M=2,13
      READ (10,100) PX(M),PM(M),R(M)
  100 FORMAT (3(XF5.0))
  301 CONTINUE
      REWIND 10
      DO 20 I=2,NM
      READ (10,100) PX(I),PM(I),RR(I)
      READ (11,101) Y(I),TY(I)
  101 FORMAT (5X,F12.0,9X,F13.0)
      READ(12,102)  EX(I),TIM(I)
  102 FORMAT (5X,F10.1,10X,F10.1)
      CALL EXAIM (Y(I),TY(I),PX(I),PM(I),R(I),X(I)
     1,TM(I),QM)
      PHIDOT(I)=X(I)-TM(I)
      WRITE (20,200) I,X(I),I,EX(I),I,TM(I),I,TIM(I),I,PHIDOT(I)
  200 FORMAT (≠X(≠,I3,≠)=≠,E13.5,2X,≠EX(≠,I3,≠)=≠,E13.5,
     12X,≠TM(≠,I3,≠)=≠,E13.5,2X,≠TIM(≠,I3,≠)=≠,E13.5,2X,
     2≠PHIDOT(≠,I3,≠)=≠,E13.5)
      CALL PHIAPHID(I)
      IF (I-13) 20,21,21
   21 CONTINUE
      CALL PHIDESS (I,PHIDES(I))
      DOTPHI(I)=PHI(I)-PHIDES(I)
      WRITE (21,202) I,PHI(I),I,PHIDES(I),I,DOTPHI(I)
  202 FORMAT (≠PHI(≠,I3,≠)=≠,E13.5,2X,≠PHIDES(≠,I3,≠)=≠,E13.5,
     12X,≠DOTPHI(≠,I3,≠)=≠,E13.5)
      A1=1.0830E-05
      BETA=1.6415E-10
      ROOT(I)=A1*R(I)+BETA*DOTPHI(I)
      CALL ROOTI(I)
      R(I+1)=362.0+RDIFF(I)
      WRITE (24,206) I,R(I),I ,RR(I),I,ROOT(I),I,RDIFF(I)
  206 FORMAT ( ≠R(≠,I3,≠)=≠,F7.2,2X,≠RR(≠,,I3,≠)=≠,F7.2
     1,2X,≠ROOT(≠,I3, ≠)=≠,F7.2,2X,≠RDIFF(≠,I3,≠)=≠,F10.5)
   20 CONTINUE
      END
      SUBROUTINE EXAIM(Y,TY,PX,PM,R,X,TM,QM)
      A=0.027189
      B=2.007798
      TTY=(TY/1073.221E 09*100.0)**1.7919/QM
      YY=(Y/53.27E 09*100.0)**0.85183/QM
      X=A*TTY*(R/360.0)**(-0.4995)*5452.0E 06/100.0
      TM=B*YY*(R/360.0)**(1.6576)*6736.0E 06/100.0
      RETURN
      END
```

For open-loop simulation, PHIDOT(I) = X(I) - TM(I), is substituted by PHIDOT(I) = EX(I) - TIM(I)

```
      SUBROUTINE PHIDESS(I,PHIDES)
      COMMON PHI(200)
      J1=I-12
      J3=I-1
      PHIDES=0.0
      DO 10 J2=J1,J3
      PHIDES=PHIDES+PHI(J2)
   10 CONTINUE
      PHIDES=PHIDES/12.
      RETURN
      END
      SUBROUTINE PHIAPHID(I)
      COMMON PHI(200),PHIDOT(200)
      N3=0
      N1=I/3
      N2=I-3*N1+1
      I5=I-2
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      IF (I-7) 55,56,56
   55 GO TO (92,92,93,94,95,96) I
   56 N3=I-4
      GO TO (82,60,71)N2
   60 DO 61 I5=2,N3,3
      SUM1=SUM1+PHIDOT(I5)+PHIDOT(I5+1)
      SUM2 =SUM2+PHIDOT(I5+2)
   61 CONTINUE
      I5=2
      GO TO 90
   71 SUM3=PHIDOT(2)
      DO 72 I5=3,N3,3
      SUM1=SUM1+PHIDOT(I5)+PHIDOT(I5+1)
      SUM2=SUM2+PHIDOT(I5+2)
   72 CONTINUE
      I5=3
      GO TO 90
   82 SUM3=PHIDOT(2)
      SUM3=(PHIDOT(2)+PHIDOT(3))/2.+SUM3
      DO 81 I5=4,N3,3
      SUM1=SUM1+PHIDOT(I5)+PHIDOT(I5+1)
      SUM2=SUM2+PHIDOT(I5+2)
   81 CONTINUE
      I5=4
      GO TO 90
   92 PHI(I)=PHIDOT(2)
      GO TO 99
   93 PHI(I)=PHIDOT(2)+(PHIDOT(2)+PHIDOT(3))/2.
      GO TO 99
   95 SUM3=PHIDOT(1)
      GO TO 94
   96 SUM3=PHIDOT(2)
      SUM3=SUM3+(PHIDOT(2)+PHIDOT(3))/2.
   94 SUM1=3.*(PHIDOT(I5)+PHIDOT(I5+1))
      GO TO 98
   90 SUM1=3.*(SUM1+PHIDOT(N3+2)+PHIDOT(N3+3))
      SUM2=2.*SUM2
   98 PHI(I)=3./8.*(PHIDOT(I5-1)+PHIDOT(I)+SUM1+SUM2)+SUM3
   99 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ROOT1(I)
      COMMON /RDIFFJ/ RDIFF(200),ROOT(200)
      K=12
      KI=I-K
      N3=0
      N1=KI/3
      N2=KI-3*N1+1
      KI5=KI-2
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      IF (KI-7) 155,156,156
  155 GO TO (192,192,193,194,195,196)KI
  156 N3=KI-4
      GO TO (182,160,171)N2
  160 DO 161 KI5=2,N3,3
      KD=KI5+K
      SUM1=SUM1+ROOT(KD)+ROOT(KD+1)
      SUM2=SUM2+ROOT(KD+2)
  161 CONTINUE
      KI5=2
      GO TO 190
  171 SUM3=(ROOT(K+1)+ROOT(K+2))/2.
      DO 172 KI5=3,N3,3
      KD=KI5+K
      SUM1=SUM1+ROOT(KD)+ROOT(KD+1)
      SUM2=SUM2+ROOT(KD+2)
  172 CONTINUE
      KI5=3
      GO TO 190
  182 SUM3=(ROOT(13)+ROOT(14))/2.
      SUM3=(ROOT(14)+ROOT(15))/2.+SUM3
      DO 181 KI5=4,N3,3
      KD=KI5+K
      SUM1=SUM1+ROOT(KD)+ROOT(KD+1)
      SUM2=SUM2+ROOT(KD+2)
  181 CONTINUE
      KI5=4
      GO TO 190
  192 RDIFF(I)=(ROOT(13)+ROOT(14))/2.
      GO TO 199
  193 RDIFF(I)=(ROOT(13)+ROOT(14))/2.+(ROOT(14)+ROOT(15))/2.
      GO TO 199
  195 SUM3=ROOT(13)
      GO TO 194
  196 SUM3=(ROOT(13)+ROOT(14))/2.
      SUM3=SUM3+(ROOT(14)+ROOT(15))/2.
  194 KD=KI5+K
      SUM1=3.*(ROOT(KD)+ROOT(KD+1))
      GO TO 198
  190 NK=N3+K
      SUM1=3.*(SUM1+ROOT(NK+2)+ROOT(NK+3))
      SUM2=2.*SUM2
  198 KD=KI5+K
      RDIFF(I)=3./8.*(ROOT(KD-1)+ROOT(I)+SUM1+SUM2)+SUM3
  199 CONTINUE
      RETURN
      END
```

I. Fortran program for closed-loop Simulation B.

```
      PROGRAM MAIN
      DIMENSION X(200),TM(200),Y(200),TY(200)
      DIMENSION R(200),RDIFF(200),RDOT(200),RR(200)
      DIMENSION PHI(200),PHIDOT(200),DOTPHI(200)
      DIMENSION PHIDES(200)
      DIMENSION PX(200),PXW(200),PM(200),PMW(200)
      DIMENSION EX(200),TIM(200)
      COMMON PHI(200),PHIDOT(200)
      COMMON /RDIFFJ/ RDIFF(200),RDOT(200)
      PHI(1)=0.0
      QM=12.0
      NM=133
      DO 301 M=2,13
      READ (10,100) PX(M),PM(M),R(M)
  100 FORMAT (3(XF5.0))
  301 CONTINUE
      REWIND 10
      DO 20 I=2,NM
      READ (10,100) PX(I),PM(I),RR(I)
      READ (11,101) Y(I),TY(I)
  101 FORMAT (5X,F12.0,9X,F13.0)
      READ(12,102) EX(I),TIM(I)
  102 FORMAT (5X,F10.1,10X,F10.1)
      CALL EXAIM (Y(I),TY(I),PX(I),PM(I),R(I),X(I)
     1,TM(I),QM)
      PHIDOT(I)=X(I)-TM(I)
      WRITE (20,200) I,X(I),I,EX(I),I,TM(I),I,TIM(I),I,PHIDOT(I)
  200 FORMAT (≠X(≠,I3,≠)=≠,E13.5,2X,≠EX(≠,I3,≠)=≠,E13.5,
     12X,≠TM(≠,I3,≠)=≠,E13.5,2X,≠TIM(≠,I3,≠)=≠,E13.5,2X,
     2≠PHIDOT(≠,I3,≠)=≠,E13.5)
      CALL PHIAPHIO(I)
      IF (I-13) 20,21,21
   21 CONTINUE
      CALL PHIDESS (I,PHIDES(I))
      DOTPHI(I)=PHI(I)-PHIDES(I)
      WRITE (21,202) I,PHI(I),I,PHIDES(I),I,DOTPHI(I)
  202 FORMAT (≠PHI(≠,I3,≠)=≠,E13.5,2X,≠PHIDES(≠,I3,≠)=≠,E13.5,
     12X,≠DOTPHI(≠,I3,≠)=≠,E13.5)
      A1=1.0830E-05
      BETA=1.6415E-10
      RDOT(I)=A1*R(I)+BETA*DOTPHI(I)
      CALL RDOTI(I)
      R(I+1)=362.0+RDIFF(I)
      WRITE (24,206) I,R(I),I ,RR(I),I,RDOT(I),I,RDIFF(I)
  206 FORMAT ( ≠R(≠,I3,≠)=≠,F7.2,2X,≠RR(≠,,I3,≠)=≠,F7.2
     1,2X,≠RDOT(≠,I3,≠)=≠,F7.2,2X,≠RDIFF(≠,I3,≠)=≠,F10.5)
   20 CONTINUE
      END
      SUBROUTINE FXAIM(Y,TY,PX,PM,R,X,TM,QM)
      A=0.0201326
      B=34197.9442
      TTY=(TY/1073.221E 09*100.0)**1.7716/QM
      YY=(Y/55.27E 09*100.0)**0.31398/QM
      X=(A*TTY*(R/360.0*100.0)**2.9511)*PX
      TM=(B*YY*(R/360.0*100.0)**0.83212)*PM
      RETURN
      END
```

```
      SUBROUTINE PHIDESS(I,PHIDES)
      COMMON PHI(200)
      J1=I-12
      J3=I-1
      PHIDES=0.0
      DO 10 J2=J1,J3
      PHIDES=PHIDES+PHI(J2)
   10 CONTINUE
      PHIDES=PHIDES/12.
      RETURN
      END
      SUBROUTINE PHIAPHID(I)
      COMMON PHI(200),PHIDOT(200)
      N3=0
      N1=I/3
      N2=I-3*N1+1
      I5=I-2
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      IF (I-7) 55,56,56
   55 GO TO (92,92,93,94,95,96) I
   56 N3=I-4
      GO TO (82,60,71)N2
   60 DO 61 I5=2,N3,3
      SUM1=SUM1+PHIDOT(I5)+PHIDOT(I5+1)
      SUM2 =SUM2+PHIDOT(I5+2)
   61 CONTINUE
      I5=2
      GO TO 90
   71 SUM3=PHIDOT(2)
      DO 72 I5=3,N3,3
      SUM1=SUM1+PHIDOT(I5)+PHIDOT(I5+1)
      SUM2=SUM2+PHIDOT(I5+2)
   72 CONTINUE
      I5=3
      GO TO 90
   82 SUM3=PHIDOT(2)
      SUM3=(PHIDOT(2)+PHIDOT(3))/2.+SUM3
      DO 81 I5=4,N3,3
      SUM1=SUM1+PHIDOT(I5)+PHIDOT(I5+1)
      SUM2=SUM2+PHIDOT(I5+2)
   81 CONTINUE
      I5=4
      GO TO 90
   92 PHI(I)=PHIDOT(2)
      GO TO 99
   93 PHI(I)=PHIDOT(2)+(PHIDOT(2)+PHIDOT(3))/2.
      GO TO 99
   95 SUM3=PHIDOT(1)
      GO TO 94
   96 SUM3=PHIDOT(2)
      SUM3=SUM3+(PHIDOT(2)+PHIDOT(3))/2.
   94 SUM1=3.*(PHIDOT(I5)+PHIDOT(I5+1))
      GO TO 98
   90 SUM1=3.*(SUM1+PHIDOT(N3+2)+PHIDOT(N3+3))
      SUM2=2.*SUM2
   98 PHI(I)=3./8.*(PHIDOT(I5-1)+PHIDOT(I)+SUM1+SUM2)+SUM3
   99 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ROOTI(I)
      COMMON /ROIFFJ/ ROIFF(200),ROOT(200)
      K=12
      KI=I-K
      N3=0
      N1=KI/3
      N2=KI-3*N1+1
      KI5=KI-2
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      IF (KI-7) 155,156,156
  155 GO TO (192,192,193,194,195,196)KI
  156 N3=KI-4
      GO TO (182,160,171)N2
  160 DO 161 KI5=2,N3,3
      KO=KI5+K
      SUM1=SUM1+ROOT(KO)+ROOT(KO+1)
      SUM2=SUM2+ROOT(KO+2)
  161 CONTINUE
      KI5=2
      GO TO 190
  171 SUM3=(ROOT(K+1)+ROOT(K+2))/2.
      DO 172 KI5=3,N3,3
      KO=KI5+K
      SUM1=SUM1+ROOT(KO)+ROOT(KO+1)
      SUM2=SUM2+ROOT(KO+2)
  172 CONTINUE
      KI5=3
      GO TO 190
  182 SUM3=(ROOT(13)+ROOT(14))/2.
      SUM3=(ROOT(14)+ROOT(15))/2.+SUM3
      DO 181 KI5=4,N3,3
      KO=KI5+K
      SUM1=SUM1+ROOT(KO)+ROOT(KO+1)
      SUM2=SUM2+ROOT(KO+2)
  181 CONTINUE
      KI5=4
      GO TO 190
  192 ROIFF(I)=(ROOT(13)+ROOT(14))/2.
      GO TO 199
  193 ROIFF(I)=(ROOT(13)+ROOT(14))/2.+(ROOT(14)+ROOT(15))/2.
      GO TO 199
  195 SUM3=ROOT(13)
      GO TO 194
  196 SUM3=(ROOT(13)+ROOT(14))/2.
      SUM3=SUM3+(ROOT(14)+ROOT(15))/2.
  194 KO=KI5+K
      SUM1=3.*(ROOT(KO)+ROOT(KO+1))
      GO TO 198
  190 NK=N3+K
      SUM1=3.*(SUM1+ROOT(NK+2)+ROOT(NK+3))
      SUM2=2.*SUM2
  198 KO=KI5+K
      ROIFF(I)=3./8.*(ROOT(KO-1)+ROOT(I)+SUM1+SUM2)+SUM3
  199 CONTINUE
      RETURN
      END
```