ECONOMICS RESEARCH REPORT

MEASUREMENT OF EFFECTIVE EXCHANGE RATES APPROPRIATE FOR AGRICULTURAL TRADE

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Economics Research Report No. 51

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North Carolina State University

November 1985

Abstract

The paper is concerned with the effect of an exchange rate variation on agricultural trade. Most related literature has dealt with specification of economic models and empirical estimation of model parameters. In contrast, this paper concentrates on the appropriate measurement of multilateral exchange rate changes for the analysis of agricultural trade. Literature on the economic theory of index numbers was reviewed for guidance in constructing effective exchange rate indices. Major existing exchange rate indices were compared including those of the Federal Reserve Board, International Monetary Fund, Morgan Guaranty Trust, and the U.S. Department of Agriculture. New indices were constructed based on alternative weighting schemes and index forms. In general, measurement differences among indices were not negligible and for certain periods, discrepancies were substantial. Of all the indices considered, the USDA's real trade-weighted dollar showed less appreciation of the dollar since 1980 than any of the other indices based on total trade or agricultural trade. This raises the question of whether the USDA index understates the importance of exchange rates when large changes occur. The significance of the results is illustrated in terms of an agricultural trade model. It appears that proper measurement of the exchange rate variable may be as important as accurate measurement of parameters of the model.

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1. Introduction

1.1. Statement of Purpose

The purpose of this paper is to analyze alternative measures of the influence of currency exchange rates on the agricultural trade of the United States. Interest in the subject increased in 1973 following the adoption of floating exchange rates by all the major countries. Most of the exchange rate changes that occurred under the earlier Bretton Woods system consisted of occasional discrete changes in bilateral rates, which were easy to measure. However, under a system of general floating, each currency depreciates or appreciates by different amounts against all other currencies, and the construction of a single index to measure the average change is not a trivial task.

A motivation for the study of exchange rates is the growing recognition that foreign variables have an important influence on American agriculture (Schuh, 1984; Tweeten, 1983; Economic Report of the President 1984, ch. 4). The overvalued dollar of 1971 that led to the demise of the Bretton Woods system depressed agricultural prices, and retarded U.S. agricultural exports (Schuh, 1974; Johnson, Grennes, and Thursby). Under floating rates, the dollar depreciated substantially in 1973-74 and again in 1979-80, even after adjusting for differences in inflation. These real depreciations increased exports and stimulated an agricultural boom in the United States. Since 1980 the dollar has appreciated substantially against most currencies, and the strength of the dollar is widely regarded to be one of the factors responsible for the decline in exports and the depressed conditions in American agriculture (Dunmore and Longmire; Batten and Belongia; Orden; Longmire, 1983; Somensatto). Although there is a consensus that exchange rates influence U.S. trade, there remains some disagreement about the magnitude of the exchange rate effects (Longmire and Morey; Chambers and Just, 1981; Johnson, Grennes, and Thursby; Batten and Belongia; Fletcher, Just, and Schmitz). Understanding of the link between exchange rates and agriculture would be improved by (a) better modeling and econometric estimation of the relevant parameters and (b) more precise measurement of the exchange rate variable. The present paper focuses on alternative measures of exchange rates relevant for agricultural trade.

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[1]Comments by Paul R. Johnson, Douglas Fisher, and Walter Thurman and cooperation by the International Economics Division of the U.S. Department of Agriculture were very helpful. Research assistance and typing were ably performed by Vicente Fretes-Cibils and Rita Edmond, respectively.

1.2. Broader Research Project

The present paper is part of a broader research project on the influence of foreign and macroeconomic variables on U.S. agricultural trade. The broader project is also concerned with determination of real exchange rates, the effect of debt repayment problems of low income countries on U.S. trade, and the relative importance of various determinants of U.S. agricultural exports. Trade depends on real exchange rates, and for many countries the behavior of real rates is quite different from that of nominal rates. The broader project attempts to explain variations in real rates and determine their impacts on agricultural trade. The present paper considers the narrower question of how to measure exchange rate adjustment in the context of multilateral trade.

1.3. Literature on Agricultural Products Trade

The issue of which exchange rate measure is most appropriate for agricultural trade has not been discussed extensively in the literature. A frequently cited paper by Chambers and Just (1981) used a dollar exchange rate based on nominal Special Drawing Rights. The U.S. Department of Agriculture has published a series for the value of the dollar in nominal terms based on agricultural trade weights (see the monthly _Agricultural Outlook_). After it became clear that the nominal series was distorted by high inflation rates in countries like Brazil and Mexico, a real series was added. Much of the discussion in the agricultural trade literature was concerned with the effect of a given exchange rate change on domestic prices and the volume of exports under the implicit assumption that the currency change had been accurately measured (Schuh, 1974; Johnson, Grennes, and Thursby; Chambers and Just 1979, 1981). It was recognized that the real exchange rate was more appropriate than the nominal rate (Johnson, Grennes, and Thursby; Collins, Meyers, and Bredahl; Longmire and Morey). It was also recognized that policies of insulating domestic prices from foreign price changes would reduce the response to an exchange rate change for any given set of domestic demand and supply elasticities (D.G. Johnson; Collins, Meyers, and Bredahl). The magnitude of the price elasticity of demand facing U.S. agriculture was discussed by Tweeten, 1977, and Paul Johnson, 1977. In his discussion of the International Monetary Fund's Multilateral Exchange Rate Model (MERM), Rhomberg warned that it was not appropriate for primary product trade.

1.4. Organization of Paper

Section 2 considers the contribution of economic theory to the measurement of effective exchange rates. The issue is a special case of an index number problem. Section 3 presents and evaluates data on existing exchange rate indices. Both aggregate indices and those specific to the agricultural sector are considered. Section 4 presents some new exchange rate measures involving global weights and variable weights and compares their performance with existing measures. The significance of the different measures is illustrated in terms of an international trade model in the fifth section. Section 6 is a summary and conclusion.

2. Economic Theory and Effective Exchange Rates

2.1. Definition of Effective Rate

Theoretical discussion of exchange rate movement frequently refers to something called "the exchange rate." Applying the concept of the exchange rate empirically, however, requires choice of a particular measure of the rate. This is so because each country has many exchange rates, one for each other country whose currency is traded in international markets. If, over a period of study, exchange rates between pairs of countries other than the one under study (in this case the United States) were constant, then, in the spirit of Hicks' composite commodity theorem, the researcher could choose the exchange rate between the home currency and <u>any</u> other single country to serve as a perfectly representative exchange rate. However, such conditions are essentially never met. Instead, exchange rates among the other countries are likely to vary substantially. Therefore, the researcher generally chooses some <u>index</u> of exchange values to represent the exchange rate. Such an index is labeled an effective exchange rate.

An effective exchange rate is analogous in many respects to a price index. Just as a price index is a composite of prices of a number of individual goods, an effective exchange rate is a composite of prices of a number of individual foreign currencies. The analogy between effective exchange rates and price indices is not perfect. Effective rates are price indices for specific sets of goods (e.g., imports, or tradebles), comprising less than the whole consumption bundle. An effective exchange rate is a measure of relative prices than of a price level. Effective exchange rates in general differ from price indices also in being measures of the value of currency composites rather than of goods composites.

2.2. Real and Nominal Exchange Rates

One important characteristic of exchange rates, including effective exchange rates, is whether they are real or nominal. According to a common definition, a real exchange rate between the currency of the home country and that of a foreign country is derived by adjusting for changes in the price levels of the two countries. A real exchange rate is defined with respect to some base period;

strictly speaking, that period should be the base period for each of the national price indices used in the computation. Such a real rate between two currencies for period t can be defined as:

$$(1) \qquad E_t^R = E_t^N (P_t/P_t^*)$$
or
$$e_t^R = e_t^N (P_t^*/P_t),$$

where E_t^R and E_t^N are real and nominal exchange rates in year t, expressed as units of foreign currency per unit of home currency, e_t^R and e_t^N are real and nominal exchange rates in year t, expressed as units of home currency per unit of foreign currency, and P_t and P_t^* are price indices for the home and foreign countries expressed as a ratio of prices in year t to prices in a common base year. Just as a nominal effective exchange rate is defined as a composite of individual nominal rates, a real effective exchange rate can be defined as a composite of individual real rates.

Real exchange rates can differ substantially from nominal ones. For example, countries like Brazil and Argentina have in recent years experienced considerable inflation. As a result, the values of their currencies in the foreign markets have declined precipitously (prices of foreign currencies have risen in terms of Argentine and Brazilian money). Yet, when we adjust the changes in nominal rates for relative inflation experiences in those countries and in the United States, we find that their exchange rates adjusted for inflation have changed much less.

2.3. Real Exchange Rates and Purchasing Power Parity

Absolute purchasing power parity[2] holds in period t when the nominal exchange rate between two countries is equal to the ratio of the price levels of those countries for that year. Algebraically, this means that:

$$(2) \qquad e_t^N = P_t/P_t^* .$$

If (2) holds and is combined with (1), where the base year for (1) is t, it is evident under these conditions that the real exchange rate in year t must equal one; i.e., whenever absolute PPP holds, the real exchange rate as defined above is unity.

A problem in computing real exchange rates is that we generally cannot determine whether or not absolute purchasing power parity holds in a given year. This is so for at least two reasons. One is that the concept of price level cannot unambiguously be defined either in theory or empirically. Defining it involves choosing one from among

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[2] See Officer for a complete review of purchasing power parity concepts. Also available is Dornbusch.

the many possible index number representations of price levels for a given country. Frequently, economic theory does not tell us which is the correct index to use; even when a particular exact index is prescribed, there are ambiguities. A second reason for difficulty is that the price levels being compared should relate to the same bundle of goods. For example, the pound price of a given consumption bundle in the United Kingdom should be compared with the dollar price of the same bundle in the United States. Such a comparison would have to be based on detailed analyses of individual commodity prices within the two countries (of the type described, for example, in Kravis and Lipsey). Partly because of the expense involved and partly because of the definitional problems raised, such analyses rarely are performed. As a result, we generally cannot claim uncontroversially that absolute purchasing power parity held in any given year.

Given the difficulty of choosing the correct base year and index, the ambiguity of real exchange rates follows. Table 1 contains indices of relative price levels and real exchange rates for the United States and Canada. These numbers illustrate how changing the base alters the real exchange rate. The real rate may be high or low depending on which base year is chosen. It is even possible for changes in the real exchange rate between two years to be in opposite directions for different choices of base year. The last three columns of Table 1 show the real value of the U.S. dollar relative to the Canadian dollar using 1970, 1976, and 1980 as alternative base periods. The 1982 U.S. dollar had decreased in real value relative to the 1976 base, but it had increased in real value relative to the 1980 base.

The real exchange rate (e_t^R) measures the amount of some composite good in the rest of the world that can be exchanged for one unit of the same good in the home country. If absolute Purchasing Power Parity holds, $e_t^R = 1$. If the home currency depreciates (e.g., $e_t^R = 1.25$), foreign goods become more expensive than comparable home goods. The change in relative prices induces an increase in the production and consumption of home goods. Since a real currency depreciation would be expected to increase exports and decrease imports, changes in real exchange rates could be used as a measure of international competitiveness. Two alternative interpretations of a change in the real rate are common but subject to criticism. One interpretation is that real rate changes, which necessarily represent deviations from Purchasing Power Parity, measure undervaluation or overvaluation which monetary authorities ought to correct (see Bergsten, also Williamson, p. 111). A second questionable interpretation is that changes in the real rate in one direction constitute a

Table 1. Indices of relative price levels and real exchange rates for the United States and Canada, 1971-1982

Year	IPL* 1970 base	IRE** 1970 base	IRE** 1976 base	IRE** 1976 base
1971	.9784	1.0221		
1972	.9484	1.0544		
1973	.9444	1.0589		
1974	.9244	1.0818		
1975	.9475	1.0554		
1976	.9033	1.1071		
1977	.9616	1.0399		
1978	1.0178	.9825		
1979	1.0655	.9385		
1980	1.1188	.8938		
1981	1.1038	.9060		
1982	1.0868	.9201	.8312	1.0084

* Calculated as $[(P_t/P_0)/(P_t^c/P_0^c)]/(e_t^N/e_0^N)$.
** IRE = 1/IPL.

forecast that the rate will move in the opposite direction in the future (see Stevens et al., p. 102 and Bergstrand). Unless there is an appropriate forward discount or premium, past rates should not systematically forecast future rates in a foreign exchange market that uses information efficiently (Roll).

2.4. Weighting Schemes

Like price indices, effective exchange rates can take many forms. Critical issues are which currencies are to be included in an index and how they are to be weighted. There are an unlimited number of ways of choosing countries and weights. The main criterion in choosing from among them should be the purpose for which the index is intended. Ideally, in analyzing international trade behavior, one would consider all the bilateral relationships involved and would use bilateral exchange rates. However, as in much other empirical analysis, aggregation is a commonly used and necessary convenience in trade studies. The nature of the study or of the phenomenon being observed dictates the countries to be included and the weights to be assigned them.

Rhomberg, in a systematic review of effective exchange rates, lists several common weighting schemes. Among them, defined for the dollar, are the following:

1. bilateral import-weighted index (an index of values of foreign currencies in terms of dollars with weights based on imports of the United States from other countries)

2. bilateral export-weighted index (an index of values of the dollar in terms of foreign currencies, with weights based on exports of the United States to the other countries)

3. average bilateral trade-weighted index (arithmetic average of 2 and the reciprocal of 1)

4. global export-weighted index (an index of values of the dollar in terms of foreign currencies, with weights based on total exports of all countries)

5. average export- weighted index (arithmetic average of 2 and 4).

6. average trade-weighted index (arithmetic average of 5 and the reciprocal of 1).

In addition to the fixed-weight forms in Rhomberg, many others are suggested by the literature on price indices.

In addition to choosing the countries and trade flows to be used in setting weights, the researcher must also choose the period when trade flows are observed for determining weights. The most common approach is to choose some base period and use the weights from that period for a number of years afterward. An alternative approach, requiring more timely data, is to update the weights each period. The weights from period t are then used to compute a change from t to t+1. The period-to-period changes are then strung together to form a chain link index. Such a chain link index can be thought of as a discrete form of a Divisia price index. It can be shown that if consumers are continuously maximizing utility, that a continuous Divisia index is exact,[3] although it also has the disadvantage of being path dependent (dependent on the path taken by prices in going from their initial to their final levels). See Diewert, 1981, or Layard and Walters for an explanation of Divisia indices. Additional, more complicated indices designed as effective exchange rates are also available in the literature (see, for example, Diehl). As will be seen below, the choice of weights and the frequency of updating the weights for an index can have substantial effects on its path.

Another major choice in defining an effective exchange rate is choosing the form in which the weights are to be

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[3] An exact index (see page 15 for a definition of exactness) of the cost of living for an individual takes a form that depends on the individual's specific utility function. Such an index can be constructed from the expenditure function of duality theory. The index is a ratio of minimum expenditure required for a given level of utility under one set of prices to the minimum expenditure required under another set of prices. A similar definition can be worked out for quantity indexes.

combined. The two most common forms are arithmetic means and geometric means. Examples of the former include the Laspeyres index used to compose the CPI, and the Paasche index underlying the implicit GNP price deflator. As will be seen below, the form of an index is related to the utility function or the production cost function of the individuals (or countries) involved. However, aside from that relationship, there are other criteria by which to discriminate among index forms. Arithmetic means in an index measure absolute changes, whereas geometric means measure proportional changes. For an arithmetic mean, if the absolute changes for all components of an index (in our case currencies) are about the same, then the effective relative weighting of the various components stays about the same through time. However, if some components increase dramatically relative to others (e.g., some exchange rates increase much more than others), then the increased ones effectively take on larger and larger weight in the index. Alternatively, if some components decrease much more than others, then they take on smaller and smaller effective weight in the index. Because geometric indices use proportional rather than absolute changes, they are not subject to that effect, and tend to be less influenced by extreme movements of components. As will be seen below, this difference can be important for determining magnitudes of effective exchange rate changes.

2.5. Indices and Economic Theory

In the case of price indices, several different criteria have been described for choosing among them. One set of criteria, of the sort described in Irving Fisher's seminal work, is based on the technical or mechanical characteristics of the indices. These include, for example, the:

1. proportionality test: if all prices rise by a given percentage, then the index should also rise by that percentage.

2. circular test: If, according to the index, the ratio of prices in period 0 to prices in period 1 is x, and the ratio of prices in period 1 to prices in period 2 is y, then the ratio of prices in period 0 to prices in period 2 should, according to the index, be xy.

3. determinate test: if any price or quantity in the index tends to zero, the index still tends to a unique positive real number.

4. commensurability test: a change in the units of measurement of commodities does not change the index.

5. factor reversal test: if we substitute prices for quantities and quantities for prices in the index formula and thereby form

a quantity index, the product of this quantity index and the price index will be the ratio of the values of the two baskets of goods in question.[4]

These criteria are not based explicitly on any theory of economic behavior, though certainly some economic theory is implicitly present. Rather, it is posited that an index should perform in a specific fashion, and each potential index is judged according to how closely it matches the prescribed mode. (It has been shown that some subsets of these tests are mutually incompatible; thus no index will satisfy them all.)

Another set of criteria is based explicitly on economic theory. For an index of consumer prices, an exact cost-of-living (Konus) index can be derived for an individual from the utility function. This index is based on the expenditure function of duality theory (see Diewert 1982 for a recent exposition of duality theory and Diewert 1981 for an excellent survey of index number theory). The expenditure function indicates the minimum expenditure required for an individual to attain a given level of utility. Its arguments are the prices facing the individual and the level of utility being attained. The cost-of-living index constructed from such a function consists of the ratio of expenditure in a given period, relative to expenditure in a base period, required for a given utility level. It can be shown that a necessary and sufficient condition for such an index to be a function of prices alone (and not utility) is that the utility function be homothetic (see, for example, Diewert 1981, for a proof). Examples of such indices are the traditional Laspeyres and Paasche, the geometric mean of prices in the new period relative to prices in the old, and Fisher's "ideal" index. The traditional Laspeyres and Paasche indices take the form:

$$I = \sum_i x_i^j p_i^1 \,/\, \sum_i x_i^j p_i^0 \ , \ j = 0,1,$$

where i indexes the goods. If j=0, then the index is the Laspeyres and if j=1, it is the Paasche. These indices are exact or Konus indices (i.e., are perfect indices of the cost of living) if utility is of the Leontief fixed-coefficient type. In that case also, the two indices equal each other. They are also exact for a linear utility function, with:

$$u = \sum_i a_i x_i.$$

The geometric index takes the form:

$$I = \sum_i w_i (p_i^1 / p_i^0),$$

where w_i is the weight for the ith good. This index is an exact or Konus index for a Cobb-Douglas utility function,

[4] These descriptions are based on descriptions in Eichorn and Voeller.

where w_i is the exponent on the ith good and the w_i's sum to one.

Fisher's ideal index takes the form:

$$I = (I_l \ I_p)^{1/2},$$

where I_l and I_p are the Laspeyres and Paasche indices. This index is exact for Leontief fixed-coefficient utility. It is also exact for homogeneous quadratic utility, where:

$$u = (\sum_i \sum_j a_{ij} x_i x_j)^{1/2}.$$

There are, of course, many other potential exact indices, one for each utility function, in fact.

Although basing a cost-of-living index on theory has much appeal, it is important to remember that empirical applications of such indices are not without problems. One is that the form of the utility function must be known or assumed. Another is that, even with knowledge of that function, it generally applies only to a particular individual. Price indices, on the other hand, are calculated for aggregates. The conditions under which aggregation does not "undermine" the exactness of the index are severe. On the other hand, any cost-of-living index we choose does imply something about the form of the utility function. It seems highly desirable to be aware of those implications.

For an index of output prices (like a GDP or GNP deflator) theory dictates that the form of the index be based on production relationships. A common approach is to use a quantity index to derive an <u>implicit</u> index of price change (the implicit GNP deflator is one example). Such an implicit index takes the form:

$$I = [\sum_i x_i^1 p_i^1 \ / \ \sum_i x_i^0 p_i^0] \ / \ Q,$$

where Q is an index of quantity change between period 0 and period 1. Fisher and Shell describe a way of basing such an index on a transformation function, or as they put it, on a production possibility mapping (PPM). A deflator function can be utilized to index production possibility frontiers in the PPM. That function in general depends on choice of a reference price vector (either the initial or final prices); however, if the PPM is homothetic, then the deflator function is independent of the price vector utilized.

An alternative to the use of an implicit price index is to base a price index on a product function. Such a function has as arguments the prices of outputs and secondary inputs, as well as the quantities of primary inputs. The function indicates the maximum value of output that can be produced, given those prices and primary inputs. It is analagous to the expenditure function in utility theory. A ratio of the product function for period t to that for period 0, with primary inputs held constant but the prices, or some subset of them, varying between the two years gives a price index. That index indicates how the value of output would be affected between the two periods by the change in prices. Diewert and Morrison (1985) contains an excellent exposition of the product function approach.[5]

2.6. Application of Theory to Effective Exchange Rates

It would be helpful in understanding effective exchange rates to be able to apply the rich body of index number theory. Of course, the "mechanical" characteristics of indices described by Irving Fisher can be applied to indices of exchange rates as to other indices. However, as noted above, those characteristics are not systematically related to economic theory. Rather, the index number theory that would be most useful to apply is that built on the theory of economic behavior. One fact that immediately emerges from attempting to apply that theory is that it is only relevant to real effective exchange rates. Theory predicts that nominal rates of exchange are not determinants or indicators of economic behavior. Nominal effective rates, being functions of nominal exchange rates, are also not indicators of behavior. Therefore, economic theory has little or nothing to say about the effects of nominal effective rates on imports or exports. To study behavior, one should employ real, or price-level adjusted, rates of exchange and effective exchange rates based on them.

Studies of import behavior frequently treat aggregate imports as a single good that is a function of an "import price." This approach suggests thinking of a real exchange rate index based on a country's imports as a sub-index of an overall cost-of-living index for that country. Such an index would then indicate the effect of a set of real exchange rate changes on the reference country's cost of purchasing the import group relative to its cost of goods in general. According to the literature (Pollak and Blackorby, Primont, and Russell), there are substantial limits on such subindices. If utility is homothetic and imports form a separable group in the utility function, then an exact subindex can be defined that is both independent of the consumption levels of goods outside the group and independent of the level of utility from consuming the group. If, however, homotheticity is relaxed, then the index will in general depend on the level of utility derived from commodities in the group. If separability is relaxed, then the index depends on the consumption levels of goods outside the group. An additional con-

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[5] A similar problem involving a quantity index appears in the monetary literature in the search for an optimal measure of the money supply. See Barnett, Offenbacher, and Spindt (1984) and Barnett (1985).

straint on such subindices is that in general they cannot be added or multiplied together to derive the overall cost of living. Only if each subindex, as well as the overall index, is a geometric mean of prices will the geometric mean of the subindices equal the overall index. The separability condition on imports has been tested empirically in a number of instances.

An example of an index of real exchange rates based on import weights is:

$$\frac{\sum_i x_i^0 e_i^{R1}}{\sum_i x_i^0 e_i^{R0}} = \frac{\sum_j x_i^0 e_i^{R0} (e_i^{R1}/e_i^{R0})}{\sum_i x_i^0 e_i^{R0}},$$

where x_i is the quantity imported by the United States from country i (for purposes of this presentation, imports from a given country are treated as a single good), and the e's are real exchange rates. This is a fixed-weight Laspeyres index analogous to the CPI in form. It is the first of the effective exchange rates listed in Rhomberg. The weights (W_j) are import values measured in dollars. Here,

$$W_j = x_j^0 e_j^{R0} / \sum_i x_i^0 e_i^{R0}.$$

Of more relevance for our purposes is an exchange rate index based on a country's exports. Such a concept suggests using a subindex of the country's output level. The subindex then would be a measure of the effect on the value of output of a set of real exchange rate changes. Following Fisher and Shell, one would construct such a subindex for years 0 and 1 as the ratio of the dollar value of exports in year 1 to the value in year 0, all divided by a quantity index of exports. The result would be an implicit index of the real exchange rate for exports. An example analogous to the implicit GNP or GDP deflator is:

$$\frac{\sum_i x_i^1 e_i^{R1}}{\sum_i x_i^0 e_i^{R0}} \Big/ \frac{\sum_i x_i^1 e_i^{R0}}{\sum_i x_i^0 e_i^{R0}} = \frac{\sum_i x_i^1 e_i^{R1}}{\sum_i x_i^1 e_i^{R0}},$$

where x_i^j is the quantity of exports to the ith country in year j and e_i^{Rj} is the real exchange rate with the currency of country i in period j expressed in terms of dollars per unit of the foreign currency. As is evident, this is equivalent to a fixed-weight Paasche index of real exchange rates. It would indicate the change in the price level of exports relative to the price level in general in the United States. The weights consist of export quantities in the final year. The fixed-weight Laspeyres version is:

$$\frac{\sum_i x_i^1 e_i^{R1}}{\sum_i x_i^0 e_i^{R0}} \Big/ \frac{\sum_i x_i^1 e_i^{R1}}{\sum_i x_i^0 e_i^{R1}} = \frac{\sum_i x_i^0 e_i^{R1}}{\sum_i x_i^0 e_i^{R0}} =$$

$$\frac{\sum_j x_j^0 e_j^{R0} (e_j^{R1} / e_j^{R0})}{\sum_i x_i^0 e_i^{R0}} = \sum w_j (e_j^{R1} / e_j^{R0})$$

As can be seen from the last term on the right, this is equivalent to a weighted sum of relative real exchange rates, with the weights being export shares in the initial year. This version is analogous to the CPI, which is a Laspeyres price index. Note that this is not identical to index number 2 in Rhomberg's list. This one uses exchange rates expressed as dollars per unit of foreign currency, whereas Rhomberg's (and many based on that form) uses exchange rates expressed as units of foreign currency per dollar. If the first form is used, the index has an economic interpretation as the ratio of the value of a given quantity of exported output in the final year relative to what that same quantity would have been worth in the base year. There is no meaning of the second form, other than as a mechanical index formula. Although in the two cases indicated above, the price indices calculated implicitly turn out to be equivalent to well-recognized explicitly calculated price indices, such a situation, in general, will not occur.

As an alternative to calculating an implicit index of the price change of exports, it is possible to compute an index directly, using a product function of the sort described above. To be exact, such a product function for exports would require separability of exports in the overall national product function. With that separability, a subindex could be defined for exports alone. If production were homothetic, then the price index for exports would be independent of the level of (sub) production occurring in the export sector. Diewert and Morrison provides a full description of such an index based on a constant returns to scale translog product function.

It is possible to calculate an "exact" effective exchange rate that combines the effects of both imports and exports. The product function approach of Diewert and Morrison is general enough to include effects of both import and export price changes. Imports are treated as negative quantities of intermediate goods. Increases in import prices thus operate negatively on the index and tend to reduce any increases in the value of output otherwise occurring.

Before departing from theoretical considerations relevant to effective rates, we should mention a different approach, that of the I.M.F.

(see Rhomberg, Maciejewski) in deriving a rate from its Multilateral Exchange Rate Model (MERM). MERM rates are constructed with weights based on balance of trade effects of exchange rate alterations. The MERM rate for the United States is a geometric index of nominal rate changes, with the weight for a particular country derived from the balance of trade effect of a 1 percent change in the rate of that country. That effect, as a fraction of total effects from a 1 percent change in the rates of all countries, comprises the weight. The index thus is based on economic behavior, and is designed to indicate economic effects (i.e., effects on the trade balance) of changes in effective rates.

3. Presentation and Evaluation of Exchange Rate Data

3.1. Bilateral Exchange Rates for Major Countries

The problem of devising an effective exchange rate index would not arise if an economic model were sufficiently complex to include a separate equation for each bilateral trade flow. In that case trade between the United States and Japan would be based on the dollar-yen rate, trade between the United States and Germany would be based on the dollar-mark rate, and averaging exchange rates would be unnecessary. Models based on the work of Paul Armington have this property, but users of those models must simplify them to make them tractable (Armington; Johnson, Grennes, and Thursby). Simplification is usually achieved by aggregating over countries, which requires exchange rate averaging.

The bilateral exchange rates between the U.S. dollar and ten major countries are presented in Table A1 of the appendix. They are the Group of Ten countries plus Switzerland, and they are the countries that comprise the Federal Reserve Board's trade-weighted dollar (Hooper and Morton).[6] These countries are important because (a) a large fraction of U.S. trade is with them, (b) their currencies are not subject to stringent exchange controls, and (c) exchange rate and price data are readily available.

Because members of the group have experienced similar inflation rates, the difference between nominal and real exchange rates is less important than for a more heterogeneous group. Column one shows actual nominal exchange rates in terms of dollars per unit of foreign currency expressed as an index number with 1971 as the base year. Column 2 shows the ratio of the normalized U.S. price level to each country's normalized price level for each year.

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[6] The Group of Ten countries is: Belgium, United Kingdom, Canada, France, West Germany, Italy, Japan, Sweden, the Netherlands, and the United States.

Column three is an index of real exchange rates, which is simply column one divided by column two times 100. It would be equal to one if purchasing power parity always prevailed. It indicates the value of U.S. goods that must be exchanged for one unit of foreign goods. Thus, an increase in the index indicates dollar depreciation. Column four shows the value of the dollar, which is simply the scale-adjusted inverse of column three. The behavior of bilateral exchange rates is useful in interpreting the exchange rate averages presented later.

3.2. Nominal Aggregate Effective Exchange Rates

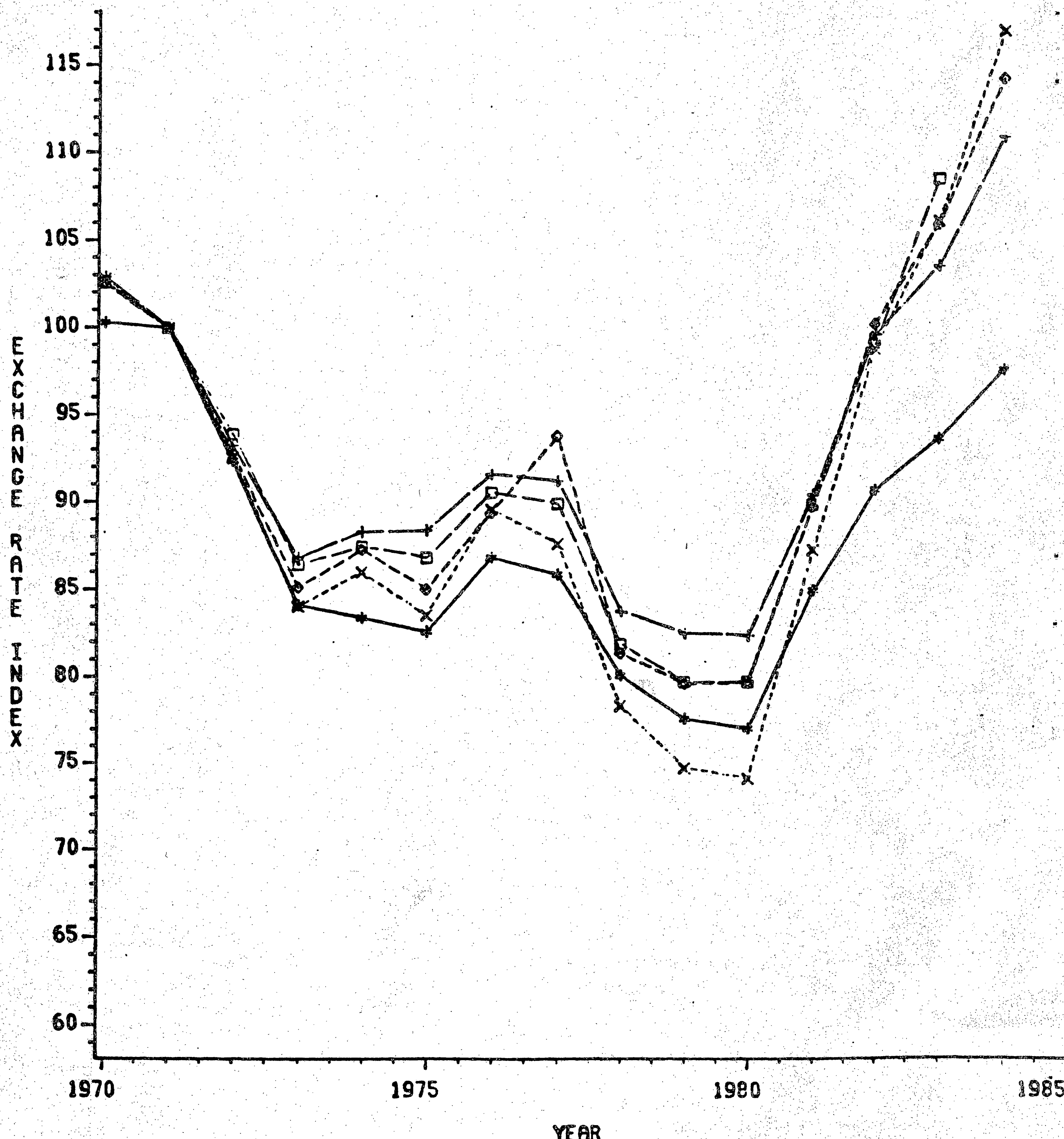
Most studies of U.S. trade treat all foreign countries as a single aggregate called the rest of the world. This treatment necessarily requires the use of an effective exchange rate index. Six of the more widely used indices will be presented. They are aggregate indices in the sense of including trade in all products. Indices for the agricultural sector and specific products will be presented later. The nominal indices are weighted averages of nominal exchange rates without adjusting for differential inflation.

The Federal Reserve Board (FRB) index is a trade-weighted average of the value of the U.S. dollar against the Group of Ten countries plus Switzerland. It is published monthly in the Federal Reserve Bulletin. The weights are based on each country's share of total trade of all countries during the period 1972-76 (Hooper and Morton, Rhomberg). The use of global trade weights rather than bilateral weights reduces the importance of Canada. In a bilaterally weighted index, Canada would be assigned a weight of 40 percent, whereas the FRB index assigns it a weight of 9 percent. The FRB index is computed as the inverse of a geometric average of exchange rates expressed as dollars per unit of foreign currency. The behavior of the FRB index (represented by letter x) and four others is shown in Figure 1 for the period 1970-84. Since 1978 it has shown the widest swings of the group. The FRB index showed the greatest depreciation of the dollar in 1980 and also the greatest appreciation in 1984.

Special Drawing Rights (SDR) are a second aggregate index. Their composition has changed since the inception of SDRs in 1970. Since 1981 an SDR has consisted of fixed amounts of U.S. dollars, German marks, Japanese yen, French francs and British pounds. According to the International Monetary Fund, which created them, the weights reflect the importance of the currencies in international trade and finance. The value of an SDR is published in the IMF's monthly International Financial Statistics and in the Wall Street Journal. As shown in Figure 1, the nominal SDR (represented by a *) has shown substan-

FIGURE 1

SELECTED NOMINAL EFFECTIVE EXCHANGE RATES
EXPRESSED AS VALUE OF DOLLAR
1970-1984



SYMBOLS:
STAR = SDR
X = FEDERAL RESERVE BOARD INDEX
DIAMOND = IMF MERM INDEX
SQUARE = OECD INDEX
PLUS = MORGAN GUARANTY TRUST INDEX

tially less appreciation of the dollar since 1980 than the other four indices. The nominal SDR was used by Chambers and Just (1981) to estimate the effects of exchange rate changes on U.S. agricultural trade.

A third aggregate index is published by the Morgan Guaranty Trust (MGT) of New York in their World Financial Markets. MGT computes separate export and import indices based on bilateral export and import shares, and their combined index is an average of the two. Because bilateral weights are used, Canada is assigned the greatest weight. The index includes 15 industrial countries. As Figure 1 indicates, the MGT shows less dollar appreciation since 1980 than the FRB or MERM, but it is more than ten points above the SDR.

A fourth set of indices is published by the U.S. Treasury Department in the quarterly Treasury Bulletin. The Treasury publishes two series using weighting schemes similar to the MGT combined index. A narrower index includes 22 members of the Organization for Economic Cooperation and Development (OECD) and a broader index includes 47 members of the IMF that account for 90 percent of total U.S. trade (Rhomberg). Variability of inflation rates among the broader group was greater than within the narrower group. The differences can be seen in appendix Table A19, where the two indices are expressed as percentage changes from their May 1970 values. By 1984 the narrow index showed dollar appreciation of 39.9 percent, whereas the broader index showed appreciation of 1736.6 percent! The latter figure demonstrates the effect of high inflation rates in certain low income countries. A similar result occurs with the USDA's nominal index (see Figure 3), which shows the importance of adjusting for differential inflation when countries have much more inflation than the United States. The Treasury indices and the USDA index use arithmetic means.

The fifth aggregate index is calculated from the International Monetary Fund's Multilateral Exchange Rate Model (MERM). Its weights (see Appendix Table A2) are derived from the Fund's trade model, which is based on the behavior of 21 countries (Rhomberg). Unlike the earlier indices that are based on historical trade shares, the MERM attempts to incorporate economic behavior based on assumed elasticities of demand and supply (Rhomberg, Maciejewski). The index purports to measure the uniform change in all bilateral exchange rates that has the same effect on the trade balance as the observed change in rates. As seen in Figure 1, the MERM showed a greater dollar appreciation in 1977 than the other three indices, and a greater appreciation than the MGT and SDR in 1983-4. The OECD publishes a sixth aggregate index for its 23 member countries based on MERM weights (see Figure 1 and the Appendix Table A19). It appears in the OECD Economic Outlook.

3.3. Real Effective Exchange Rates

If the nominal dollar depreciates by an amount equal to the difference between U.S. and foreign inflation, relative prices and trade should be unaffected. Thus, nominal exchange rates may be a misleading measure of the effect of currency markets on international trade. Real exchange rates are designed to adjust nominal rates for differential inflation in the countries involved. Since the adjustment is based on Purchasing Power Parity, changes in the real rate measure deviations from PPP and changes in relative prices. The MGT index is published in both nominal and real form. We have converted the FRB, MERM and SDR into real indices by using consumer prices reported by the IMF.[7] These real effective exchange rates for the period 1970-84 are shown in Figure 2 along with the USDA real agricultural dollar.[8] Note that unlike the nominal rates, the real rates tend to converge after 1980. However, there are substantial differences among the aggregate indices between 1971 and 1980. For most of that period, the SDR showed the strongest dollar and the FRB the weakest dollar relative to 1971 levels and the difference between them exceeded ten index points at times. By 1984 the FRB index showed the strongest dollar. The tendency of the USDA index to show a weaker dollar since 1980 than alternative indices will be discussed below.

3.4. Effective Exchange Rates for the Agricultural Sector and Specific Products

It is clear from the theoretical discussion of section 2, as well as from the literature that index weights should be determined by the use for which the index is designed (Allen, Maciejewski). Thus, if users are interested in explaining agricultural exports, weights based on agricultural trade may be more appropriate than weights based on total trade. This justification has been offered for the agricultural trade-weighted dollar published by the U.S. Department of Agriculture in its Agricultural Outlook.

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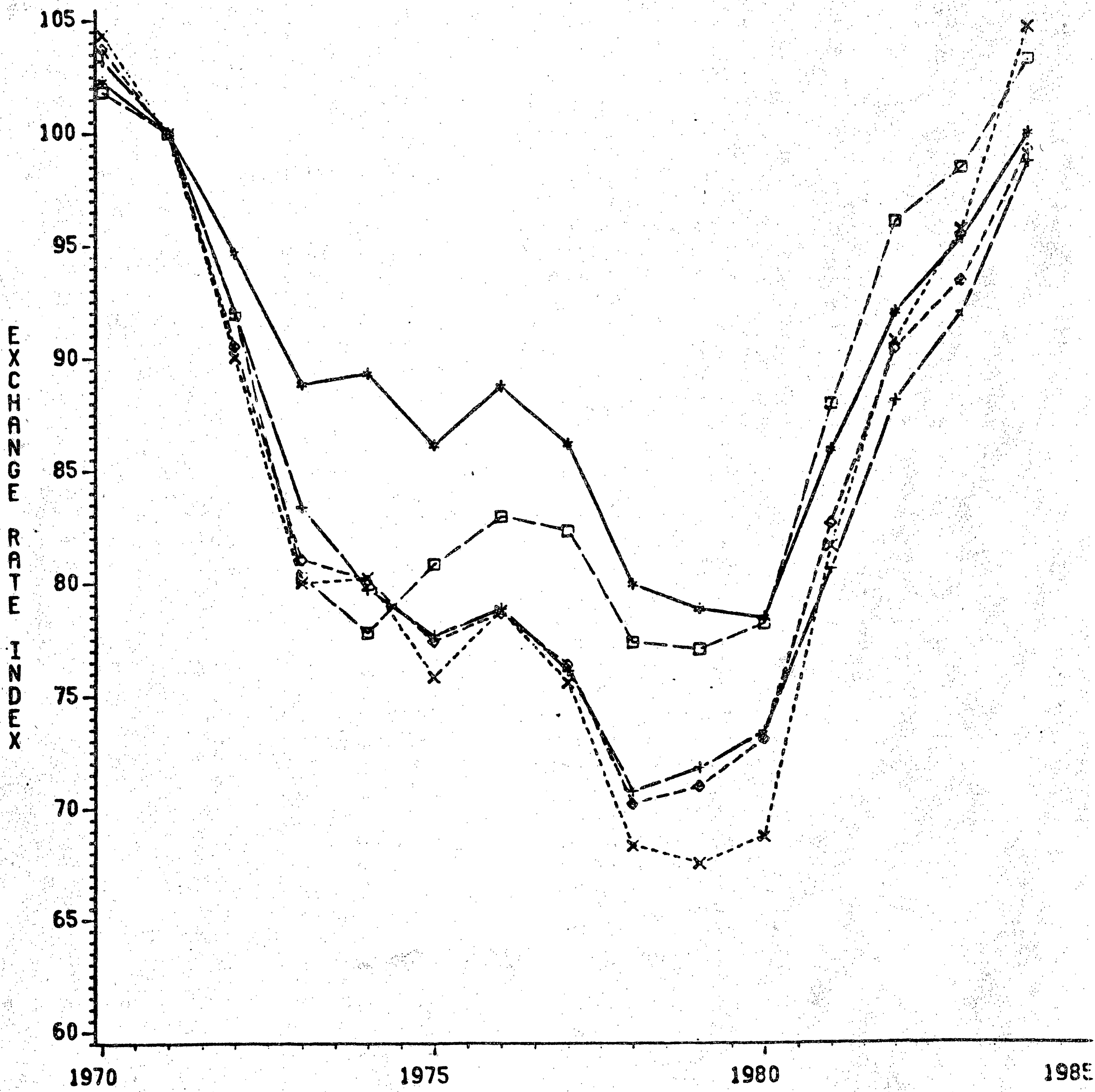
[7] The FRB, MERM, and SDR real indices here have been constructed back to 1970 using the most recent sets of country weights published for those indices.

[8] The agricultural indices here and in Figure 3 are taken from USDA quarterly figures, arithmetically averaged to four annual versions. In Figures 4-13, all agricultural indices were recreated using raw data. This was to make the USDA index form comparable to other forms (e.g., geometric indices). In some cases, slight discrepancies appear between our versions and official USDA versions, presumably because of rounding differences, differences in methods of handling missing data, etc.

FIGURE 2

SELECTED REAL EFFECTIVE EXCHANGE RATES
EXPRESSED AS VALUE OF DOLLAR
1970-1984



SYMBOLS:
STAR = SDR
X = FEDERAL RESERVE BOARD INDEX
DIAMOND = IMF MERM INDEX
SQUARE = MORGAN GUARANTY TRUST INDEX
PLUS = USDA AGRICULTURAL INDEX

Indices are computed for total agricultural trade and for the following individual crops: wheat, corn, soybeans, and cotton. They appear in both nominal and real form with bilateral export weights. Hence, the weights reflect the relative importance of historical buyers of U.S. exports. An implicit assumption in this choice of weights is that the main competitors are producers in the importing country (Maciejewski). Thus competing agricultural exporters such as Canada, Australia, and Argentina are assigned small or zero weights.

The behavior of the nominal agricultural indices is shown in Figures 3 and 4. Figure 3 compares the total agricultural index with the FRB index for all trade. Even though both are nominal indices, the FRB fluctuates mildly without a clear trend. Its 1984 value is close to its 1970 value. Conversely, the agricultural index is very sensitive to recent events, and its 1984 value exceeded 800. This result probably reflects the large weight given to high inflation countries in the USDA index.

Figure 4 compares the nominal total agriculture index with four indices using trade weights for individual products. They move closely together until the late 1970s. After 1980 the wheat index, the corn index, and the total agriculture indices appreciate much more than the indices of other products. The result probably reflects higher inflation in countries that have bought U.S. wheat.

The effects of adjusting for relative inflation rates are shown in Figure 5. The relationship between the real total agriculture index and the real FRB, and SDR indices is also shown. Relative positions of the indices change over time, but after 1980 the total agriculture index shows a lower dollar value relative to 1971 than any of the aggregate indices. The USDA index shows the real value of the dollar below its 1971 value in 1984, but FRB and SDR both show a real dollar value in 1984 equal to or greater than the 1971 value (MGT and MERM also show greater appreciation than the USDA index. See Table A21). Figure 6 shows the real agricultural index relative to real indices for the four specific products. They follow a similar pattern, with the wheat index showing the greatest appreciation since 1980. However, none of the indices reach their 1971 values by 1984.

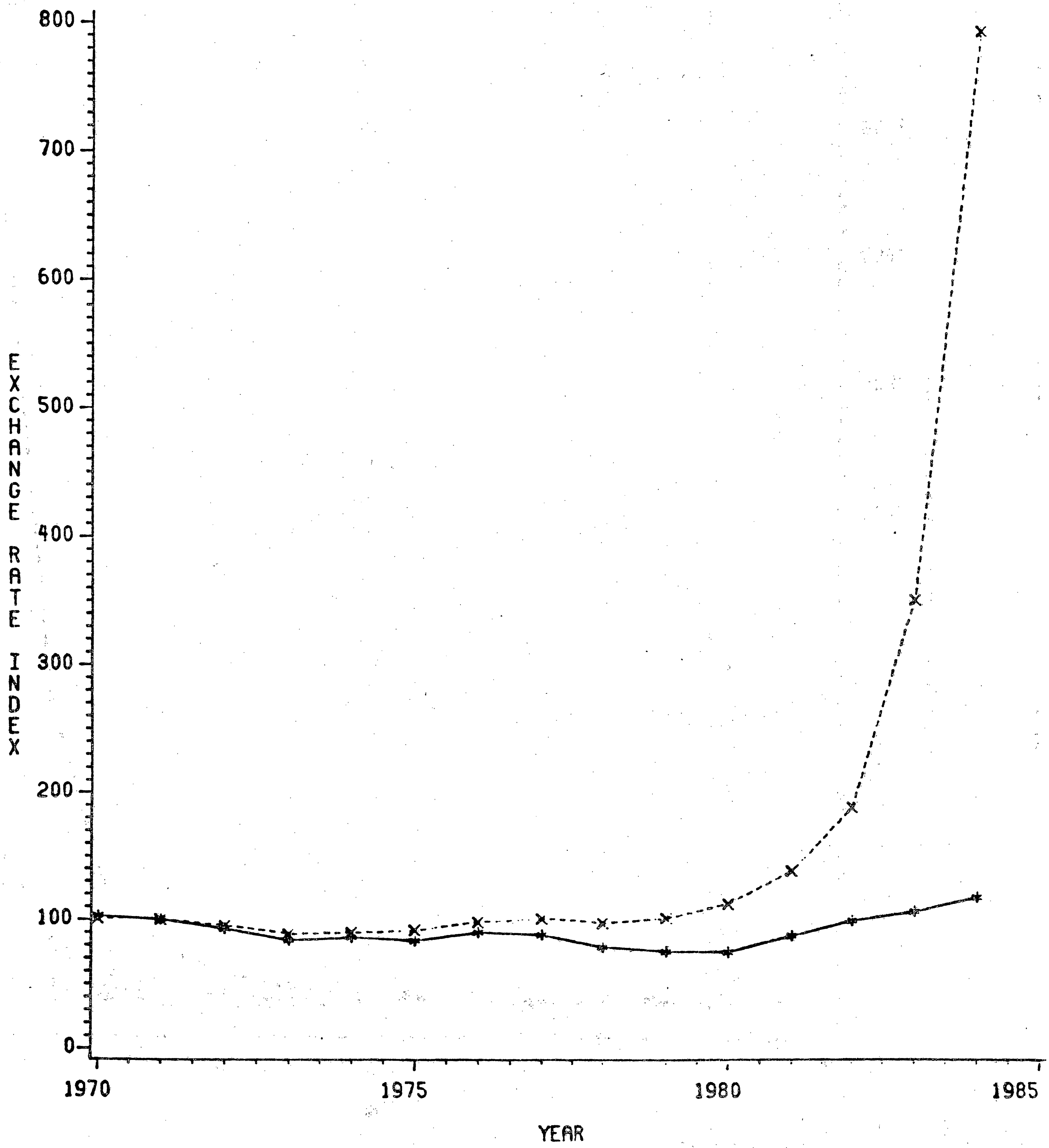
4. Alternative Measures of Effective Exchange Rates for Agriculture

4.1. Index Forms

A variety of index forms have been used for effective exchange rates. The USDA agricultural index is an arithmetic mean of foreign exchange rate values of the dollar. The SDR index is an arithmetic mean of the dollar value of foreign exchange. The FRB index is a geometric mean of dollar values of foreign ex-

FIGURE 3

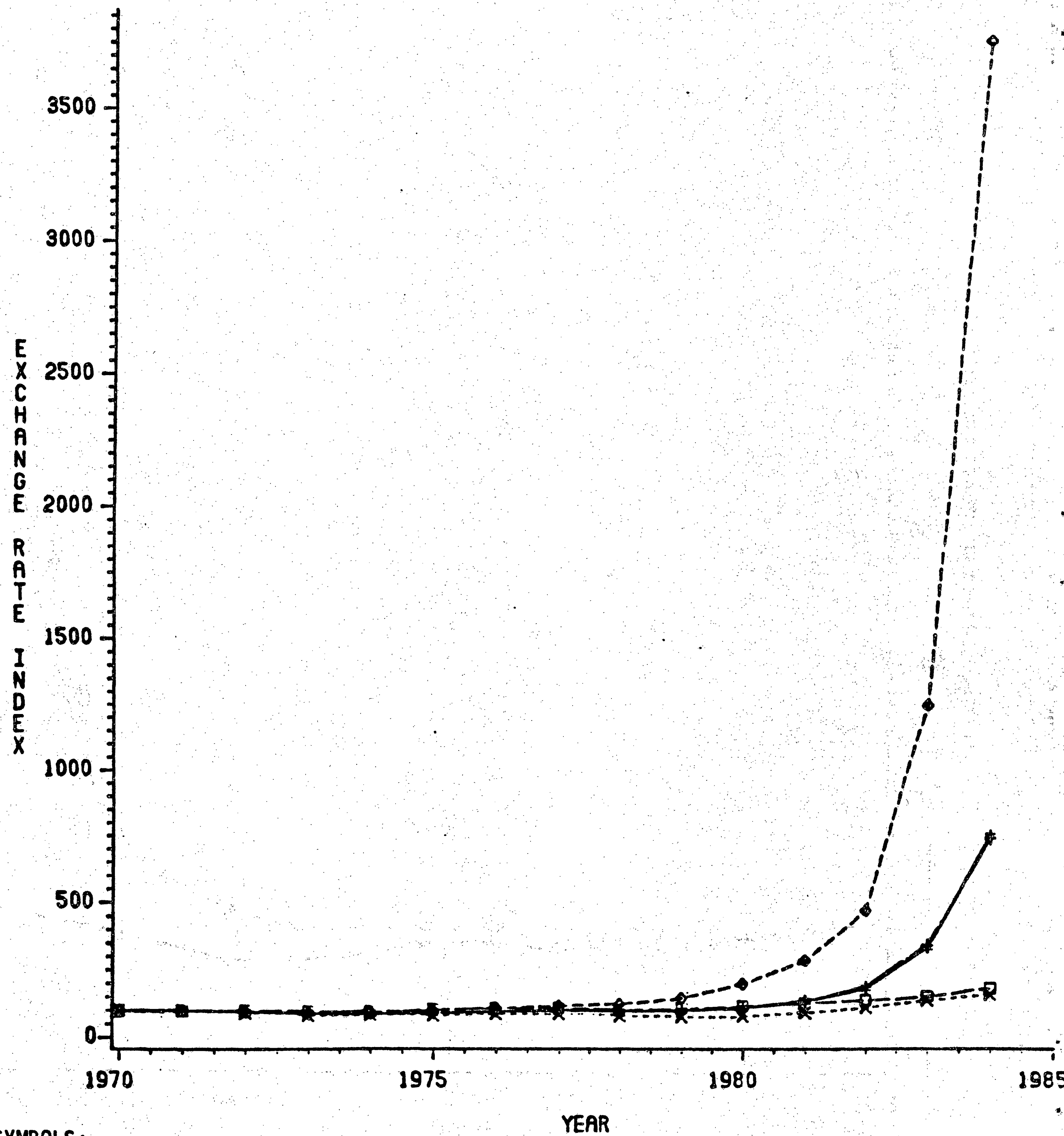
SELECTED NOMINAL EFFECTIVE EXCHANGE RATES
EXPRESSED AS VALUE OF DOLLAR
1970-1984



SYMBOLS:
X = USDA INDEX FOR AGRICULTURAL EXPORTS
STAR = FEDERAL RESERVE BOARD INDEX

FIGURE 4

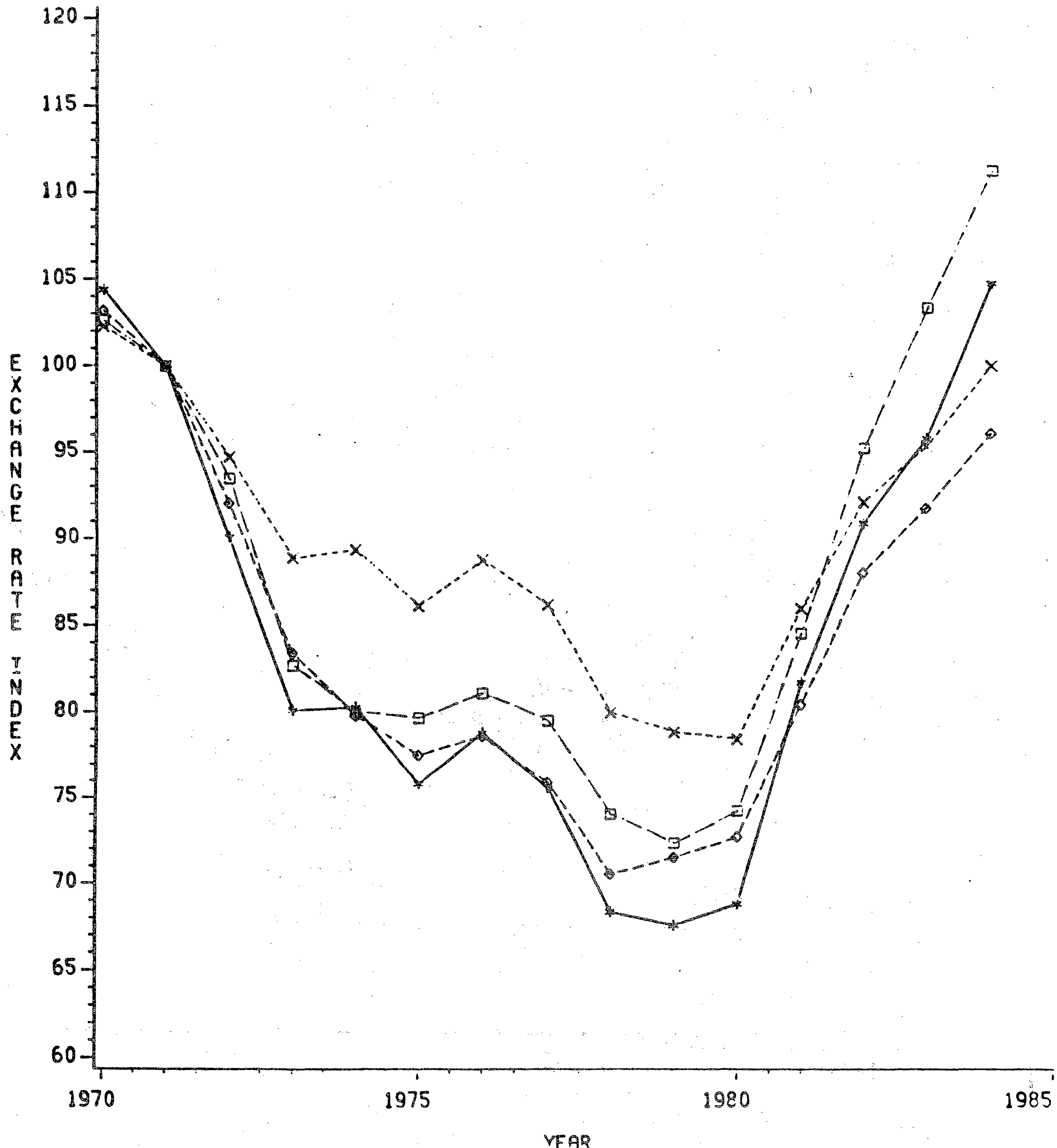
NOMINAL AGRICULTURAL EFFECTIVE EXCHANGE RATES
ARITHMETIC MEANS FOR TOTAL AGRICULTURE AND 4 CROPS
EXPRESSED AS VALUE OF DOLLAR, 1976-78 WEIGHTS
1970-1984



SYMBOLS:
STAR = TOTAL AGRICULTURE
X = SOYBEANS
DIAMOND = WHEAT
SQUARE = COTTON
PLUS = CORN

FIGURE 5

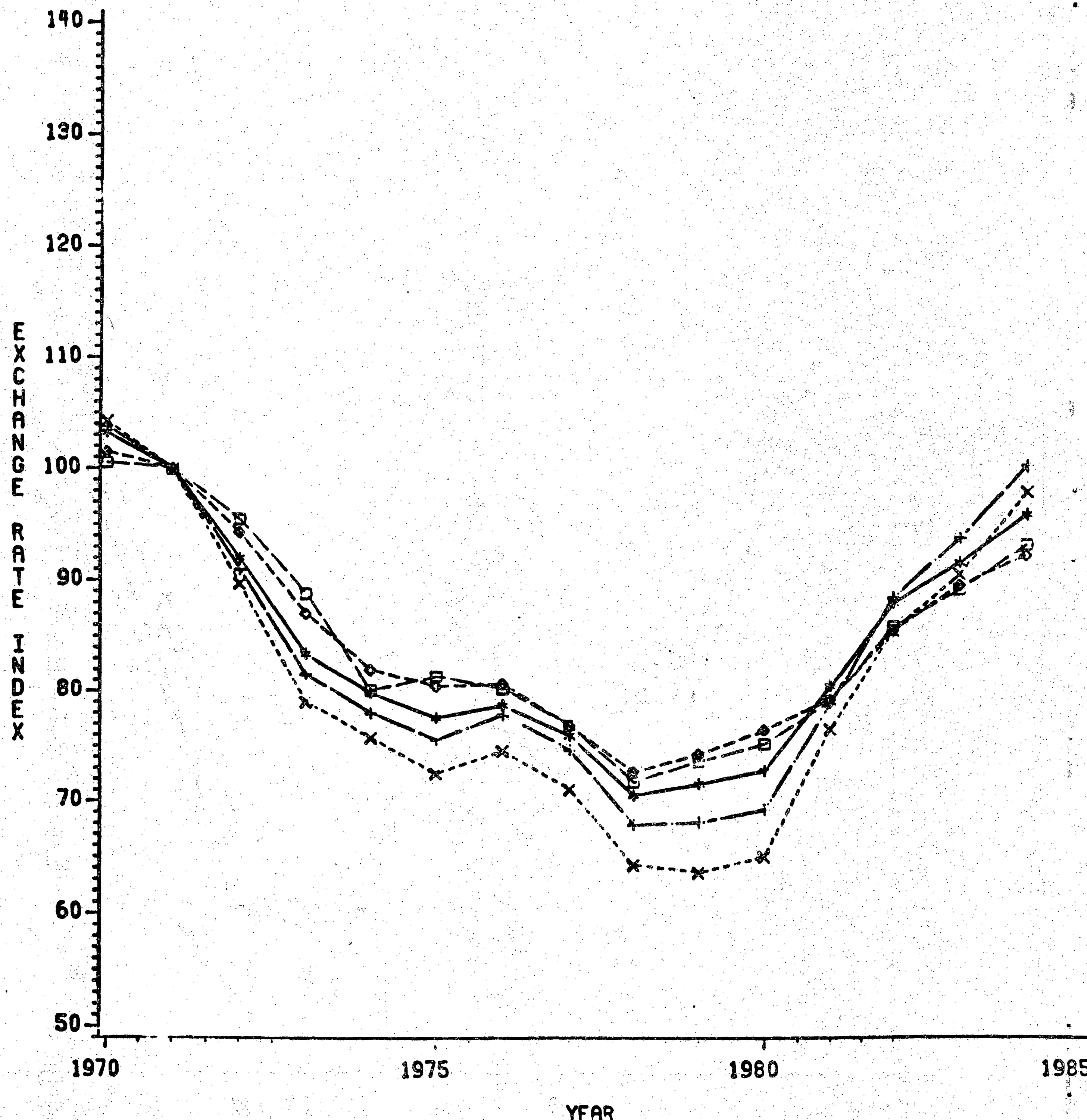
SELECTED REAL EFFECTIVE EXCHANGE RATES
EXPRESSED AS VALUE OF DOLLAR
1970-1984



SYMBOLS:
STAR = FEDERAL RESERVE BOARD INDEX
X = SDR
DIAMOND = USDA INDEX FOR AGRICULTURAL EXPORTS
SQUARE = GLOBAL WEIGHT INDEX FOR AGRICULTURAL EXPORTS

FIGURE 6

REAL AGRICULTURAL EFFECTIVE EXCHANGE RATES
ARITHMETIC MEANS FOR TOTAL AGRICULTURAL AND 4 CROPS
EXPRESSED AS VALUE OF DOLLAR, 1976-78, WEIGHTS
1970-1984



SYMBOLS:
STAR = TOTAL AGRICULTURE
X = SOYBEANS
DIAMOND = WHEAT
SQUARE = COTTON
PLUS = CORN

change. (Both the SDR and FRB indices generally are shown inverted so as to indicate the value of the dollar.)

To see what difference the index form makes, we have computed indices using USDA weights for the 38 chief purchasers of U.S. agricultural exports. Figure 7 illustrates the first three of the following four index forms:

a. arithmetic mean of foreign exchange value of the dollar;

b. arithmetic mean of dollar value of foreign exchange with total inverted to be comparable to a;

c. geometric mean of foreign exchange value of the dollar; and

d. geometric mean of dollar value of foreign exchange, with total inverted to be comparable to c (This form is mathematically equivalent to c).

These four types have been used in various instances. For example, the USDA index is type a, the FRB index is type d, the MERM index is type c, and the SDR index (as computed here) is type b.

It is surprising how much the three agricultural indices of Figure 7, all purporting to measure the same thing, differ among themselves. Type a shows by far the most movement. It is dominated by absolute changes in the nominal exchange rates of high inflation countries like Brazil. If we compute the index using the inverted form of the nominal exchange rate (dollars per unit of foreign exchange) and then invert the total (type b), the movement of the nominal exchange rate shrinks dramatically. The effect of the high inflation countries, rather than dominating the whole, simply disappears.

The geometric index ends up between the other two. The effects of the high inflation countries are toned down because proportional rather than absolute changes matter. By the same token, inverting the exchange rates being entered does not remove entirely the effects of those countries.

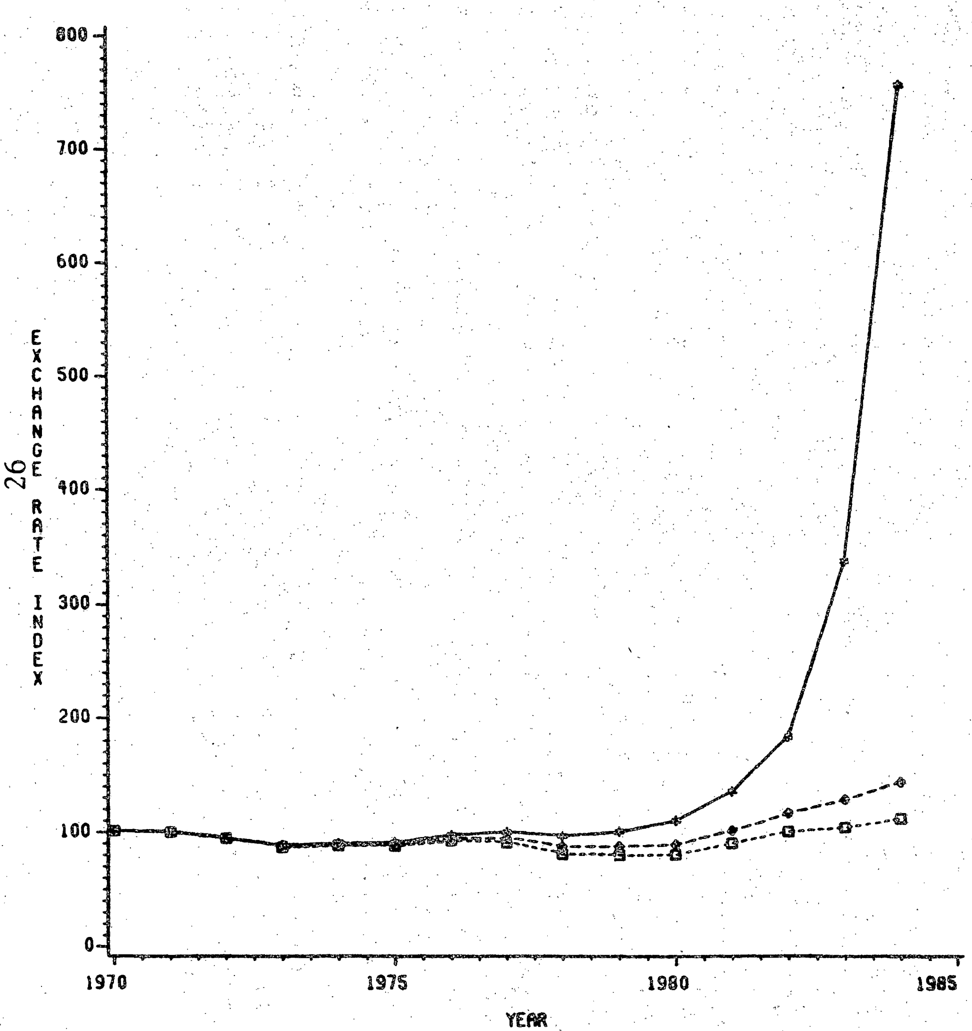
Figure 8 indicates the same set of rates in real form. Price adjustment removes the huge exchange rate changes that occur as a result of inflation. Consequently, the three forms of effective exchange rates shown are fairly close together. Nevertheless, in 1983 there still was a spread among them of 5 percent relative to a 1971 base (see Table A5). This percentage is substantial relative to the levels of "overvaluation" or "undervaluation" of the dollar that are mentioned frequently in policy discussions.

4.2. Weighting

A wide variety of weighting schemes exists for computing effective exchange rates. One source of variation is the period chosen for observing

FIGURE 7

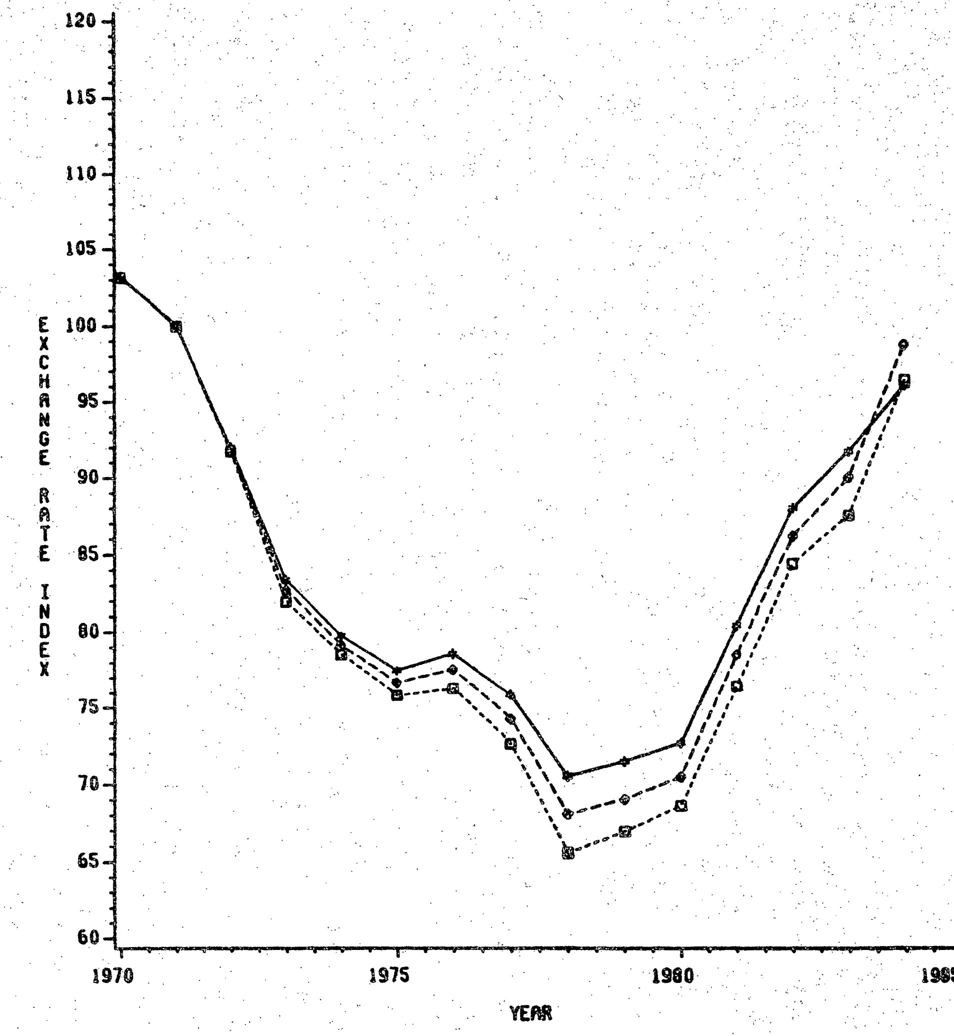
NOMINAL AGRICULTURAL EFFECTIVE EXCHANGE RATES
EXPRESSED AS VALUE OF DOLLAR, 1976-78 US EXPORT WEIGHTS
1970-1984



SYMBOLS:
STAR = ARITHMETIC MEAN
SQUARE = INVERSE OF ARITHMETIC MEAN
DIAMOND = GEOMETRIC MEAN

FIGURE 8

REAL AGRICULTURAL EFFECTIVE EXCHANGE RATES
EXPRESSED AS VALUE OF DOLLAR, 1976-78 US EXPORT WEIGHTS
1970-1984



SYMBOLS:
STAR = ARITHMETIC MEAN
SQUARE = INVERSE OF ARITHMETIC MEAN
DIAMOND = GEOMETRIC MEAN

the trade flows or other weight-determining activity. The USDA agricultural index uses U.S. export weights from the 1976-78 period. We present a series using 1981-83 weights for U.S. exports (the weights appear in Table 2). Another possible variant is to use a new set of weights each year. Using U.S. exports to compose weights, we have derived a chain link effective exchange rate.

An even more important variation than the year, for our purposes, is the set of trade flows or activities underlying computation of the weights. It seems natural to use U.S. export weights in analyzing U.S. exports. Such weights represent the importance of countries as buyers of U.S. agricultural production. However, it fails completely to capture the importance of competing exporters. For example, in the case of wheat, Canada, Australia, and Argentina are assigned zero weights and France receives a weight of less than 1 percent (see Table 2) even though these are the four largest wheat exporters after the United States. If we used the U.S. export weighted index alone to study our wheat exports, we would be implicitly assuming that U.S. wheat exports decrease if the dollar appreciates against currencies of wheat-importing countries but not if the dollar appreciates against wheat exporters. To overcome this gap, we consider agricultural trade-weighted indices based on global agricultural trade.

In the case of total agricultural trade, weights were constructed based on global agricultural exports, net of exports to the United States. The 24 largest agricultural exporters were included in the weighting scheme. To make the resulting effective exchange rates comparable to the USDA index, weights were based on average trade for the 1976-78 period. These global weights are shown in Table 2.

In addition to the weights for total exports, weights were constructed for each of four individual products. Each major exporter's share of total world exports of that product, net of exports to the United States, was used to determine weights. See Table 2 for a complete presentation of weights. For wheat, the global export shares are: Canada, 42.2 percent, Australia, 26.3 percent, France, 19.8 percent, and Argentina, 11.7 percent. Notice that these countries receive approximately zero weight in the U.S. export weight scheme. Conversely, Japan, which receives the largest weights in that scheme, receives zero weight using the global approach. Similarly, the global soybean weights differ substantially from the U.S. export weights. In the former, Brazil has a preponderant weight of 70.6 percent and in the latter a weight of zero.

4.3. Empirical Results of Weighting Methods

The relationship between bilateral (U.S. export weighted) and global weight indices for total agricultural trade is shown in Figure 9. The indices presented are inverted geometric means of the dollar value of foreign currencies. The index based on global weights demonstrates a substantially greater real appreciation of the dollar since 1980. By 1984 the global weight index was 11 percent above its 1971 value, whereas the bilateral weight index was 4 percent below its 1971 value (see Tables A5 and A6 for exact values).

The tendency for the global weight index to indicate a stronger dollar also shows up for the individual crops in Figures 10 through 13 (also presenting inverted geometric means). The most extreme real appreciation occurs for the soybean global weight index (Figure 10). In 1984 the value of the dollar according to the bilateral weight index had not quite reattained its 1971 level; the global weight index, in contrast, registers a dollar value increase of more than 50 percent. Cotton and corn indices also show dramatic divergences in the 1980s. Both levels and rates of increase of the value of the dollar are distinctly different for the bilateral and the global weight indices, with the global weight dollar being stronger in both cases. Wheat shows least difference overall between the bilateral and global weight indices. However, through most of the latter 1970s, the global weight wheat dollar was much stronger than the bilateral weight wheat dollar.

A note of caution at this point - these indices, like others, are subject to measurement error. For example, there may be some bias inherent in the inflation adjustment. The widest divergences between index types seem to have occurred in cases in which high inflation countries entered the global index with large weights. For example, the soybean index is dominated by Brazil and Argentina. Throughout the paper we have relied on CPI figures reported in _International Financial Statistics_ for our inflation adjustment. One might prefer other price indices for adjustment, such as the GDP deflator. However, for the wide range of countries included in our computations, the CPI was generally included whereas the deflator frequently was not.

In addition to considering changes from using global rather than U.S. export trade, we also look at results of altering the weights but keeping the same 38 countries in the USDA indices. In particular, we construct an index employing weights taken from a more recent period (1981-83) and a chain link index using a new set of initial period weights for each period. The inverted geometric mean forms of these indices are presented in Figure 9 along with a similar index using 1976-78 weights. It is evident that among those three the choice

Table 2. Bilateral and global weights for agricultural trade-weighted indices

Country	U.S. Exports[b]	U.S. Exports[a]	Global Exports	U.S. Soybeans	Global Soybeans
JAPAN	0.211	0.204	0.005	0.228	.
NETHERLANDS	0.113	0.100	0.135	0.246	0.091
GERMANY	0.090	0.053	0.077	0.099	0.058
CANADA	0.083	0.063	0.049	0.026	.
ITALY	0.048	0.032	.	0.059	.
KOREA	0.047	0.060	0.005	0.013	.
UNITED KINGDOM	0.046	0.030	0.059	0.034	.
SPAIN	0.037	0.046	0.025	0.087	.
MEXICO	0.034	0.062	0.007	0.029	.
TAIWAN	0.034	0.040	.	0.053	.
FRANCE	0.027	0.019	0.132	0.032	.
BELGIUM	0.026	0.029	0.052	0.031	0.039
IRAN	0.020	0.003	.	.	.
INDIA	0.017	0.017	0.022	.	.
VENEZUELA	0.017	0.025	.	.	.
PORTUGAL	0.016	0.022	.	0.010	.
BRAZIL	0.015	0.019	0.072	.	0.706
EGYPT	0.014	0.031	.	.	.
SWITZERLAND	0.012	0.011	.	0.006	.
NIGERIA	0.012	0.015	.	.	.
SAUDI ARABIA	0.011	0.016	.	.	.
DENMARK	0.010	0.005	0.041	0.024	.
INDONESIA	0.010	0.014	0.014	0.006	.
PHILIPPINES	0.008	0.011	0.012	.	.
GREECE	0.008	0.006	.	0.004	.
ALGERIA	0.007	0.007	.	.	.
THAILAND	0.006	0.005	0.027	.	.
COLOMBIA	0.006	0.008	0.017	.	.
NORWAY	0.006	0.006	0.003	0.015	.
DOMINICAN REPUBLIC	0.006	0.006	.	.	.
PERU	0.006	0.011	.	.	.
AUSTRALIA	.	.	0.067	.	.
ARGENTINA	.	.	0.048	.	0.107
MALAYSIA	.	0.004	0.027	.	.
SOUTH AFRICA	.	.	0.019	.	.
TURKEY	.	.	0.016	.	.
SINGAPORE	.	.	0.010	.	.
KENYA	.	0.001	0.008	.	.
ECUADOR	.	0.004	.	.	.
SYRIAN ARAB REP.	.	.	.	.	.
BANGLADESH	.	0.004	.	.	.
PAKISTAN	.	.	.	.	.
GHANA	.	0.001	.	.	.
MOROCCO	.	0.006	.	.	.
SUDAN	.	0.002	.	.	.

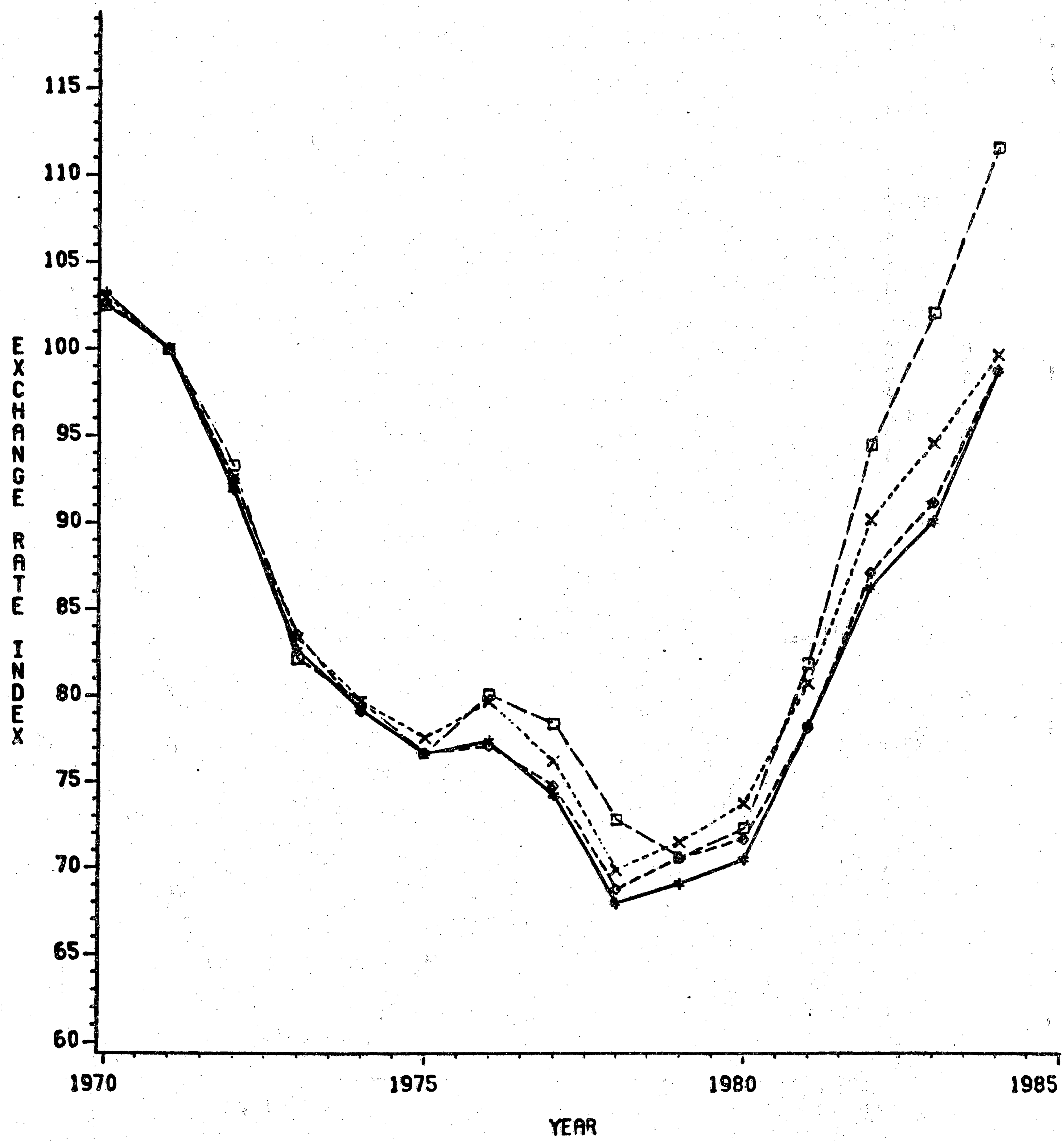
Table 2 (continued)

COUNTRY	U.S. Wheat	Global Wheat	U.S. Cotton	Global Cotton	U.S. Corn	Global Corn
JAPAN	0.209	.	0.258	.	0.254	.
NETHERLANDS	0.044	.	0.004	.	0.121	0.126
GERMANY	0.022	.	0.013	.	0.122	.
CANADA	.	0.422	0.051	.	0.012	.
ITALY	0.024	.	0.022	.	0.078	.
KOREA	0.083	.	0.257	.	0.042	.
UNITED KINGDOM	0.006	.	0.015	.	0.064	.
SPAIN	0.006	.	0.018	.	0.049	.
MEXICO	0.021	.	.	0.123	0.044	.
TAIWAN	0.035	.	0.099	.	0.043	.
FRANCE	0.007	0.198	0.015	.	0.007	0.125
BELGIUM	.	.	.	.	0.051	0.056
IRAN	0.057	.	.	0.068	0.005	.
INDIA	0.063	.	0.033	.	.	.
VENEZUELA	0.044	.	.	.	.	.
PORTUGAL	0.019	.	0.010	.	0.043	.
BRAZIL	0.094	.	.	.	0.014	0.067
EGYPT	0.008	.	0.017	0.115	0.015	.
SWITZERLAND	.	.	0.021	.	.	.
NIGERIA	0.047	.	.	.	.	.
SAUDI ARABIA	0.025	.	.	.	.	.
INDONESIA	0.018	.	0.053	.	.	.
PHILIPPINES	0.032	.	0.023	.	.	.
GREECE	.	.	0.008	.	0.033	.
ALGERIA	0.036	.	.	.	.	.
THAILAND	.	.	0.040	.	.	0.136
COLOMBIA	0.021	.	.	.	.	.
DOMINICAN REPUBLIC	0.011	.	.	.	.	.
PERU	0.023	.	.	.	0.006	.
AUSTRALIA	.	0.263	.	.	.	.
ARGENTINA	.	0.117	.	.	.	0.333
MALAYSIA	.	.	0.011	.	.	.
SOUTH AFRICA	.	.	.	.	.	0.157
TURKEY	.	.	.	0.203	.	.
ECUADOR	0.015	.	.	.	.	.
GUATEMALA	.	.	.	0.093	.	.
NICARAGUA	.	.	.	0.093	.	.
SYRIAN ARAB REP.	.	.	.	0.096	.	.
BANGLADESH	.	.	0.026	.	.	.
PAKISTAN	.	.	.	0.058	.	.
GHANA	.	.	0.007	.	.	.
MOROCCO	0.024	.	.	.	.	.
SUDAN	0.008	.	.	0.152	.	.

[a] 1981-83 U.S. export weights.
[b] 1976-78 U.S. export weights.

FIGURE 9

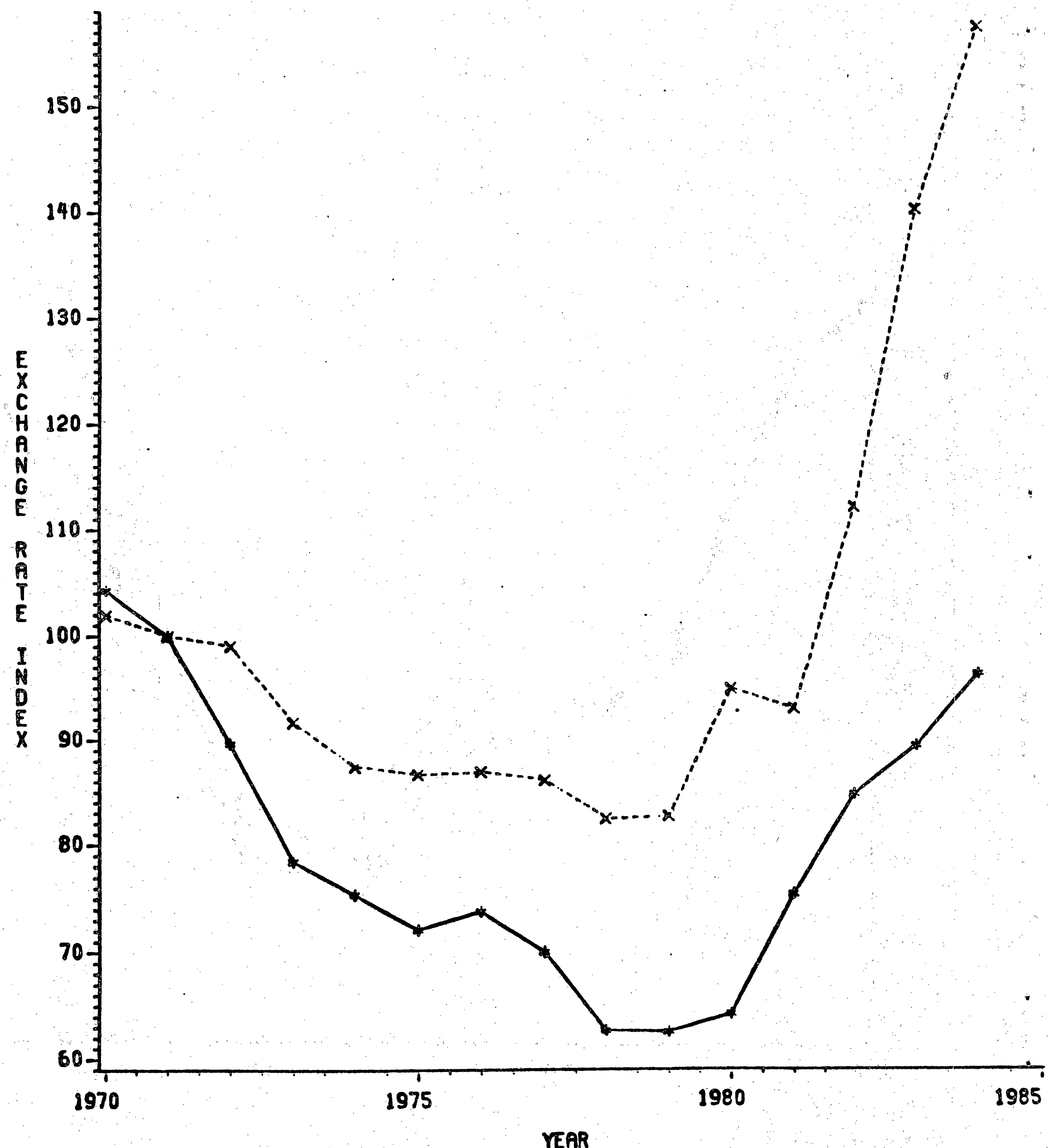
REAL AGRICULTURAL EFFECTIVE EXCHANGE RATES
GEOMETRIC MEANS
EXPRESSED AS VALUE OF DOLLAR
1970-1984



SYMBOLS:
STAR = INVERSE INDEX, 76-78 US EXPORT WTS
X = INVERSE INDEX, CHAIN LINK, US EXPORT WTS
DIAMOND = INVERSE INDEX, 81-83 US EXPORT WTS
SQUARE = INVERSE INDEX, 76-78 GLOBAL EXPORT WTS

FIGURE 10

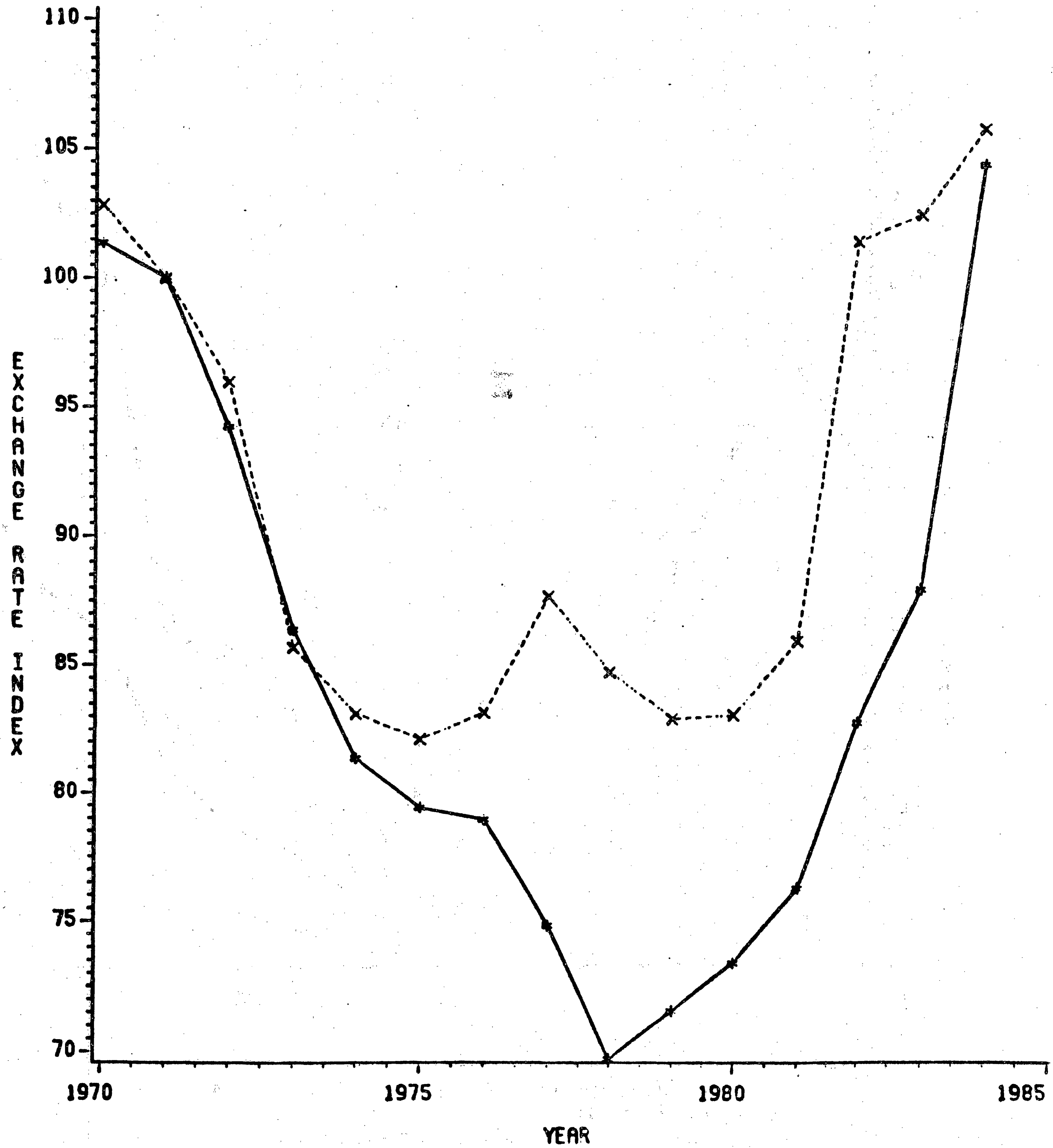
REAL AGRICULTURAL EFFECTIVE EXCHANGE RATES, SOYBEANS
GEOMETRIC MEANS
EXPRESSED AS VALUE OF DOLLAR
1970-1984



SYMBOLS:
STAR = INVERSE INDEX, 76-78 US EXPORT WTS
X = INVERSE INDEX, 76-78 GLOBAL EXPORT WTS

FIGURE 11

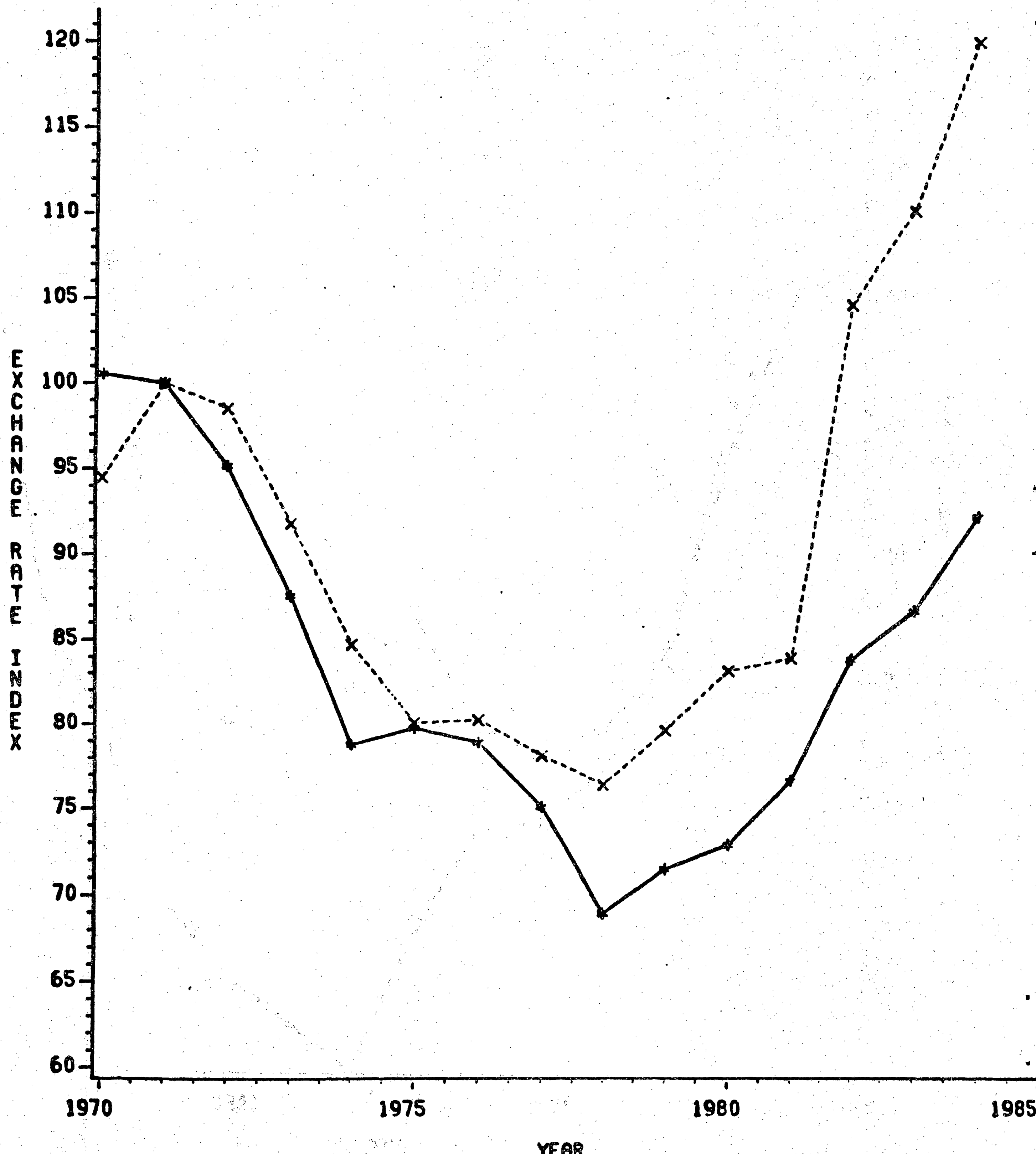
REAL AGRICULTURAL EFFECTIVE EXCHANGE RATES, WHEAT
GEOMETRIC MEANS
EXPRESSED AS VALUE OF DOLLAR
1970-1984



SYMBOLS:
STAR = INVERSE INDEX, 76-78 US EXPORT WTS
X = INVERSE INDEX, 76-78 GLOBAL EXPORT WTS

FIGURE 12

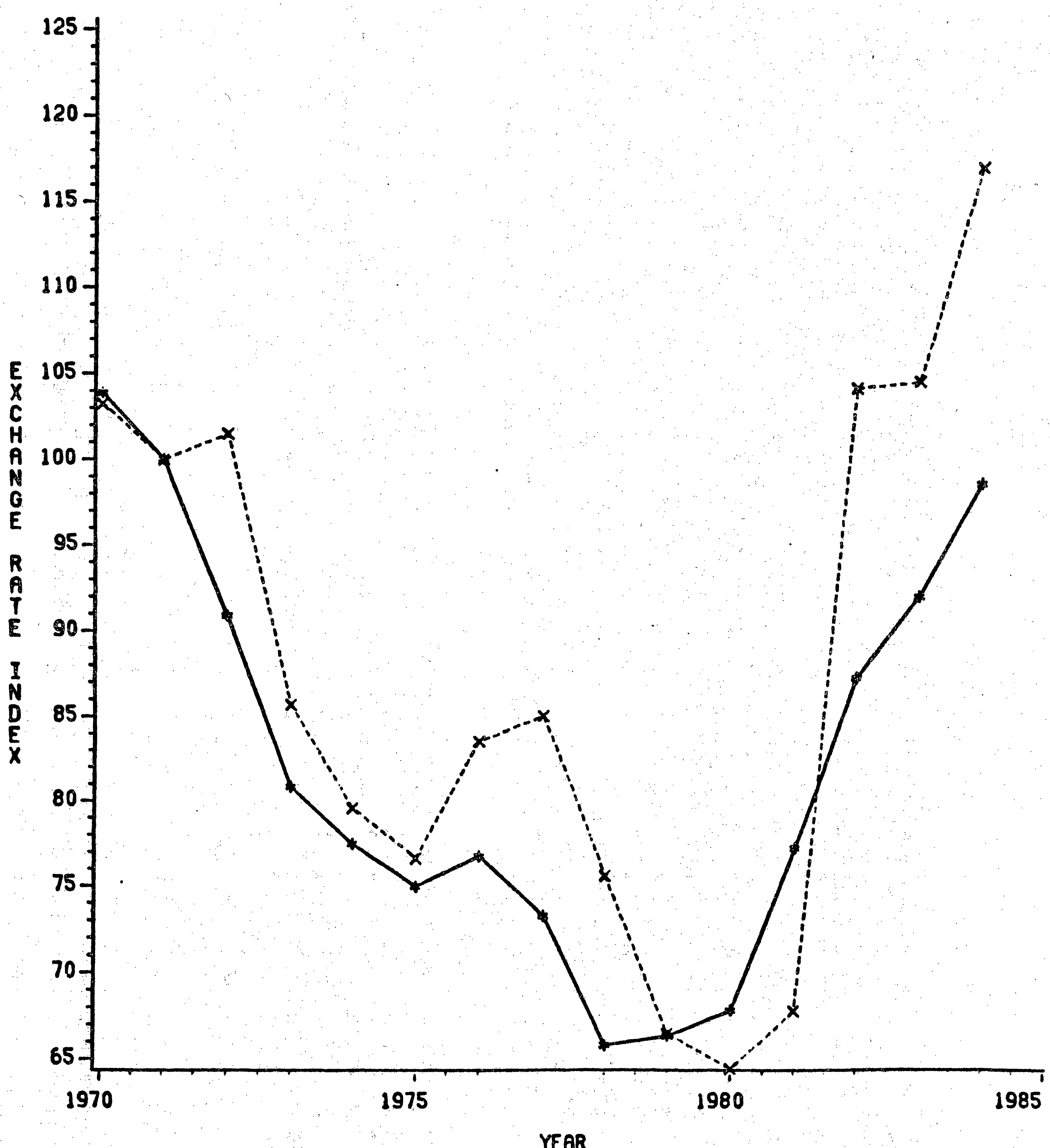
REAL AGRICULTURAL EFFECTIVE EXCHANGE RATES, COTTON
GEOMETRIC MEANS
EXPRESSED AS VALUE OF DOLLAR
1970-1984



SYMBOLS:
STAR = INVERSE INDEX, 76-78 US EXPORTS WTS
X = INVERSE INDEX, 76-78 GLOBAL EXPORT WTS

FIGURE 13

REAL AGRICULTURAL EFFECTIVE EXCHANGE RATES, CORN
GEOMETRIC MEANS
EXPRESSED AS VALUE OF DOLLAR
1970-1984



SYMBOLS:
STAR = INVERSE INDEX, 76-78 US EXPORT WTS
X = INVERSE INDEX, 76-78 GLOBAL EXPORT WTS

of weight scheme makes relatively little difference, at least for indices of real rates. Major divergences like those between bilateral and global weight indices are absent. However, the differences are not entirely negligible. If we were discussing "overvaluation" or "undervaluation" of the dollar, the largest difference among the various weighting schemes in 1983, for example, would be almost 5 percent - a number sufficiently large to warrant notice.

There is no clear justification in Figure 9 to pick one index over another. However, any single base period eventually would recede too far into the past to be reliable for weighting. Updating will be necessary from time to time. This fact is a plus in favor of a chain link index. Another plus is that the weights used in computing the change between any two time periods would always be recent ones.[9]

A final set of comparisons relies on Figure 5, which shows two aggregate trade indices (FRB and SDR), the USDA bilateral weight index and the global weight index. All except the FRB are presented in greatest appreciation of the arithmetic form. The global weight index shows by far the dollar (111.3 in 1984). The FRB (104.7 in 1984) and SRD (100.0 in 1984) indices show intermediate appreciation (see Table A5, A6 and A21 for complete data). The USDA bilateral weight index, which shows the least dollar appreciation (96.1), had not regained its 1971 real value by 1984. The USDA index closely followed the MERM index (see Table A21) until 1981, when MERM showed a faster appreciation. The observation that the bilateral agricultural trade-weighted index shows less appreciation than any of the aggregate trade indices or the global weight agricultural index leads to the question of whether the use of the USDA index presents a misleading representation of the effect of international currency markets on U.S. agriculture.

In future research we intend to investigate further the divergences among the indices presented, particularly between the bilateral and global indices for agriculture. One interpretation of the two indices is that the bilateral index represents the relative price of U.S. agricultural exports abroad, and the global index represents the price of substitute products. In attempting to explain U.S. exports, one would certainly want to consider both, particularly in light of the divergences between them. It may be that U.S. agriculture has suffered in its competitive position abroad more because of the movement of com-

[9]A problem in using a chain link index is obtaining data to compute the weights in a timely way. However, the most recently available weights could always be used for preliminary figures, with revised figures being issued when the weighting data had become available.

petitors' exchange rates relative to world levels than because of importers' exchange rates against the dollar.

5. Illustration of Exchange Rate Results in Terms of an Agricultural Trade Model

5.1. Features of the Longmire-Morey Model

The effect of currency appreciation on prices and exports depends on (a) the structure of the economic model employed, (b) the values of supply and demand elasticities, and (c) the index used to measure the exchange rate change. To demonstrate the significance of exchange rate measurement, it will be instructive to employ a trade model whose basic structure and parameter values represent a broad consensus of the profession. A simple trade model for the United States presented by Longmire and Morey will serve.

The Longmire-Morey model represents a kind of synthesis of work done in agricultural trade. It incorporates some of the features of Armington-type models that were employed to analyze the effect of exchange rate changes on wheat trade (Johnson, Grennes, and Thursby). It treats the markets for wheat, corn, and soybeans as a simultaneous system (Chambers and Just, 1979 and 1981). The model permits imperfect transmission of prices between countries (Collins, Meyers, and Bredahl). It incorporates an inventory equation that can be used to represent a government price support program (Paarlberg, Webb, and Morey; Sharples). It is dynamic in the sense of generating a response distributed over twenty years, although most of the adjustment occurs within two years (Chambers and Just, 1981). The assumed price elasticities of demand and supply represent consensus estimates from the agricultural economics literature (see Table 3).

The model generates coefficients that show the effect of a 1 percent real appreciation of the dollar on the dollar prices and volume of exports and inventories of wheat, corn, and soybeans. The response coefficients are shown in Table 4 as separate columns labeled Case 1 and Case 2. In Case 1 it is assumed that the elasticities take the values shown in Table 3 and prices are perfectly transmitted between countries. For example, Case 1 implies that a real appreciation of the dollar by 10 percent would lower wheat prices by 6.94 percent, reduce wheat exports by 7.19 percent, and increase U.S. wheat inventories by 5.47 percent. The effects on the corn and soybean markets are shown in the same column.

Case 2 is designed to incorporate the effects of (a) price-insulating trade policies, and (b) binding price support programs in the United States. Thus, it is assumed that price transmission is imperfect, and inventory demand is significantly more elastic than in Case 1. In

Case 2 a 10 percent real appreciation would reduce the dollar price of wheat by 2.17 percent, reduce U.S. wheat exports by 9.53 percent and increase U.S. wheat inventories by 22.67 percent. Thus, there is a smaller price and export volume effect because more wheat is diverted into domestic inventories. A third set of coefficients from Chambers and Just ,1981, is shown separately in appendix Table A20. Since they show more responsive prices and export volume, they are shown for purposes of comparison.

5.2. Effects of Exchange Rate Change on Wheat, Corn, and Soybeans Using Alternative Measures of Effective Exchange Rates

The agricultural trade literature has demonstrated a legitimate interest in developing accurate measures of response coefficients for prices and export volumes. However, it may be equally important to develop accurate measures of exchange rate changes. For example, a 10 percent appreciation combined with a response coefficient of 0.8 is analytically equivalent to a 20 percent appreciation combined with a response coefficient of 0.4. Consider the effect of dollar appreciation on U.S. agriculture in 1983. Two alternative measures of trade-weighted dollar appreciation are shown in Table 5. The four rows show exchange rate appreciation between 1982 and 1983 for total agricultural trade, wheat, corn, and soybeans, respectively.

Column 1 employs bilateral weights published by USDA. They are based on the percentages of total U.S. agricultural exports bought by each foreign country. Column 2 employs global weights for each product category. They are each country's exports of each product divided by world exports of that product (excluding U.S. exports). Bilateral weights emphasize buyers of U.S. exports, whereas global weights emphasize competing sellers. For example, in the case of wheat, bilateral weights include many low-income countries, but global weights include only Canada, Australia, France, and Argentina.

For total agricultural trade, bilateral weights show appreciation of 4.25 percent in 1983, but global weights show appreciation of 8.26 percent. Bilateral weights show a substantially smaller appreciation for soybean trade, 5.96 percent versus 27.20 percent. Conversely, bilateral weights result in greater appreciation for both wheat and soybeans. Global weights show approximately no exchange rate change, whereas bilateral rates show appreciation of 4.83 percent and 6.15 percent for wheat and corn, respectively.

Implications of the alternative exchange rate measures can be seen by applying the response coefficients from the Longmire-Morey model shown

Table 3. Price elasticities of demand and supply underlying the Longmire-Morey model

Own and Cross-price Elasticities of Demand			
Quantity	Wheat	Corn	Soybeans
Price			
Wheat	-.20	.05	.05
Corn	.05	-.40	.10
Soybeans	.05	.10	-.40

Supply Elasticities			
Quantity	Wheat	Corn	Soybeans
Price			
Wheat	.40	-.15	.05
Corn	-.15	.40	.30
Soybeans	-.05	-.30	+.40

Source: Longmire and Morey, pp. 30-31.

Table 4. Effect of a 1% real appreciation of the dollar on the following variables after two years:

	Case 1[a]	Case2[b]
Price Wheat	-.694%	-.217%
Price corn	-.628	-.269
Price soybeans	-.590	-.385
Wheat exports	-.719	-.953
Corn exports	-.603	-.991
Soybean exports	-.510	-.488
Wheat inventories	+.547	+2.262
Corn inventories	+.670	+3.033
Soybean inventories	+.588	+ .328

[a]Assumes the own and cross-price elasticities shown in Table 3 and perfect price transmission.
[b]Assumes wheat and corn prices near the support level and less than perfect price transmission.

Source: Jim Longmire and Art Morey. Strong Dollar Dampens Demand for U.S. Farm Exports. U.S.D.A. Foreign Agricultural Economic Report Number 193, December 1983, first two columns of Tables 5 and 7.

Table 5. Alternative measures of dollar appreciation, 1983

	Bilateral Weights USDA (percent)	Global Weights (percent)
Total Agriculture	+4.25	+8.26
Wheat	+4.83	+0.01
Corn	+6.15	+0.01
Soybeans	+5.96	+27.20

in Table 6. The use of bilateral weights implies that 1983 currency market conditions taken by themselves would lower dollar prices of wheat and corn by 3.5 percent and 3.6 percent. However, global weights imply no effect from exchange rates in 1983. In the case of soybeans, bilateral weights imply a 3.6 percent decline in prices, but global weights imply a decrease of nearly four times as much. The differences for exports show a similar pattern. In the case of soybean exports, global weights imply a decline of more than four times as much as bilateral weights. In terms of 1982 exports of 32 million metric tons, one measure of dollar appreciation implies a reduction in soybean exports of 4.3 million tons, but the alternative measure shows a reduction of only 1.0 million tons. The differences resulting from alternative measures of exchange rates would be magnified if larger response coefficients were employed (see the Chambers-Just coefficients in appendix Table A20).

6. Summary and Conclusion

Increased variability of exchange rates since 1971 has stimulated interest in the relationship between exchange rates and agricultural trade. Part of the research effort has focused on model specification and empirical estimation of response coefficients that would show the effect of a given exchange rate change on agricultural trade. A separate but related question involves the appropriate measurement of exchange rate changes in a world of multilateral trade. The construction of a single exchange rate measure when bilateral exchange rates move by different amounts and in different directions is a traditional index number problem.

This paper has reviewed the literature on the economic theory of index numbers in an attempt to provide guidance to the construction of an effective exchange rate measure relevant to agricultural trade. The major existing effective exchange rate indices were compared, including both indices of total trade and agricultural trade. Various new indices were calculated by considering various weighting schemes and index forms. The sensitivity of fixed weight bilateral trade indices, such as the USDA's trade-weighted dollar, was

Table 6. Effect of alternative measures of 1983 real dollar appreciation

	Response[a] Coefficient	USDA Bilateral Weights (percent)	Global Weights (percent)
Prices			
Wheat	-.7	-3.5	0
Corn	-.6	- 3.6	0
Soybeans	-.6	-3.6	-14.2
Exports			
Wheat	-.7	-3.5	0
Corn	-.6	-3.6	0
Soybeans	-.5	-3.0	-13.2

[a]From Longmire -Morey model Case 1.

analyzed by altering the base year, substituting global trade weights, and varying weights with a chain link index. The sensitivity of effective exchange rate indices to the use of arithmetic and geometric means was also analyzed.

The most dramatic set of measurement differences were those between real effective exchange rates computed using U.S. agricultural export weights and rates computed with global export weights. A reasonable' interpretation is that the U.S. export- weighted indices represent the price of U.S. products relative to that of domestic products in importing countries, whereas the global weight indices represent the price of products of competing exporters. Both presumably would be important in a model explaining U.S. exports.

In addition to the effects of weighting differences, we have presented effects of index form differences. For real exchange rates, those differences seem fairly small. For nominal effective exchange rates, however, the differences can be considerable. In general, the geometric indices seem superior to the arithmetic ones. Since they measure proportional rather than absolute exchange rate changes, they tend to emphasize extreme movements of particular individual exchange rates less than the arithmetic means.

In general, differences in measured appreciation among indices were not negligible. In many cases the magnitude of the measured differences among indices was as large as the magnitude of differences among extreme response coefficients found in the literature on agricultural trade. Measurement differences have been particularly large since the dollar began appreciating in 1981. During this recent period, the USDA`s index of the real trade-weighted dollar has shown less appreciation than any of the aggregate trade indices or agricultural indices based on global trade weights. Thus, for any economic model used to analyze trade, the USDA index would show a smaller effect of exchange rates on agricultural trade than any of the alternative measures. More work is necessary before one can determine the best index or set of indices for the study of agricultural trade, but the results of this paper indicate the importance of additional research.

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APPENDICES

Appendix A

Appendix Table 1. Bilateral exchange rate and relative price level indices for United States and Group of Ten Countries

(1971 = 100 for each series)

YEAR	e[a]	CPIUS/CPI[b]	Real e (1)/(2)	Real E (2)/(1)
		BELGIUM		
1970	97.623	100.034	97.590	102.470
1971	100.000	100.000	100.000	100.000
1972	110.900	97.990	113.175	88.359
1973	125.680	97.419	129.010	77.514
1974	125.514	95.854	130.943	76.369
1975	133.094	92.819	143.391	69.739
1976	126.651	89.929	140.834	71.005
1977	136.252	89.484	152.264	65.675
1978	155.235	92.060	168.625	59.303
1979	166.564	98.129	169.739	58.914
1980	167.169	104.413	160.104	62.459
1981	132.054	107.075	123.329	81.084
1982	106.829	104.551	102.179	97.867
1983	95.462	100.221	95.251	104.985
1984	84.472	97.819	86.356	115.800

[a]Dollars per unit of foreign currency expressed as index with1971 base.

[b]CPI of US divided by CPI of foreign country.

CANADA

YEAR	e[a]	CPIUS/CPI[b]	Real e (1)/(2)	Real E (2)/(1)
1970	96.455	98.609	97.815	102.234
1971	100.000	100.000	100.000	100.000
1972	102.012	98.547	103.516	96.603
1973	100.968	97.426	103.636	96.492
1974	103.253	97.393	106.017	94.324
1975	99.286	96.011	103.412	96.701
1976	102.426	94.492	108.397	92.254
1977	95.019	93.199	101.953	98.085
1978	88.570	91.988	96.284	103.860
1979	86.215	93.786	91.927	108.782
1980	86.371	96.642	89.373	111.891
1981	84.232	94.888	88.770	112.651
1982	81.848	90.771	90.169	110.902
1983	81.934	88.592	92.485	108.126
1984	83.527	88.579	94.296	106.049

[a]Dollars per unit of foreign currency expressed as index with 1971 base.

[b]CPI of US divided by CPI of foreign country.

FRANCE

YEAR	e[a]	CPIUS/CPI[b]	Real e (1)/(2)	Real E (2)/(1)
1970	99.787	101.155	98.647	101.371
1971	100.000	100.000	100.000	100.000
1972	109.885	97.263	112.977	88.514
1973	124.875	96.302	129.670	77.119
1974	115.176	93.908	122.647	81.535
1975	129.478	91.755	141.113	70.865
1976	116.145	88.574	131.128	76.261
1977	112.819	86.245	130.812	76.446
1978	123.041	85.021	144.719	69.100
1979	130.341	85.482	152.477	65.584
1980	131.344	85.605	153.431	65.176
1981	102.574	83.369	123.037	81.277
1982	84.328	78.754	107.078	93.390
1983	72.722	74.166	98.054	101.985
1984	63.420	72.083	87.983	113.659

[a]Dollars per unit of foreign currency expressed as index with 1971 base.

[b]CPI of US divided by CPI of foreign country.

GERMANY

YEAR	e[a]	CPIUS/CPI[b]	Real e (1)/(2)	Real E (2)/(1)
1970	95.219	100.917	94.353	105.985
1971	100.000	100.000	100.000	100.000
1972	109.298	97.814	111.741	89.493
1973	131.544	97.262	135.247	73.939
1974	134.751	100.776	133.713	74.787
1975	141.995	103.856	136.723	73.141
1976	138.515	105.350	131.481	76.057
1977	150.225	108.276	138.743	72.076
1978	173.864	113.298	153.457	65.165
1979	190.296	121.196	157.015	63.688
1980	192.063	130.331	147.365	67.859
1981	154.815	135.849	113.961	87.750
1982	143.617	136.421	105.275	94.990
1983	136.490	136.339	100.111	99.889
1984	122.457	138.883	88.173	113.414

[a] Dollars per unit of foreign currency expressed as index with 1971 base.

[b] CPI of US divided by CPI of foreign country.

ITALY

YEAR	e[a]	CPIUS/CPI[b]	Real e (1)/(2)	Real E (2)/(1)
1970	99.194	100.639	98.565	101.456
1971	100.000	100.000	100.000	100.000
1972	106.324	97.744	108.778	91.930
1973	106.386	93.777	113.445	88.149
1974	95.102	87.332	108.898	91.829
1975	95.040	81.516	116.591	85.770
1976	74.768	73.839	101.258	98.758
1977	70.242	67.204	104.520	95.676
1978	73.094	64.447	113.417	88.171
1979	74.644	62.516	119.400	83.752
1980	72.536	58.537	123.914	80.701
1981	54.929	54.842	100.159	99.841
1982	45.838	50.732	90.354	110.675
1983	40.819	47.389	86.137	116.094
1984	35.285	46.120	76.508	130.706

[a] Dollars per unit of foreign currency expressed as index with 1971 base.

[b] CPI of US divided by CPI of foreign country.

JAPAN

YEAR	e[a]	CPIUS/CPI[b]	Real e (1)/(2)	Real E (2)/(1)
1970	96.963	101.829	95.222	105.018
1971	100.000	100.000	100.000	100.000
1972	115.148	98.986	116.328	85.964
1973	128.656	94.105	136.715	73.145
1974	119.616	83.931	142.518	70.167
1975	117.627	81.915	143.596	69.640
1976	117.731	79.292	148.478	67.350
1977	130.401	78.169	166.819	59.945
1978	167.435	80.979	206.762	48.365
1979	159.895	87.010	183.766	54.417
1980	154.555	91.408	169.083	59.143
1981	158.639	96.203	164.900	60.643
1982	140.132	99.373	141.016	70.914
1983	146.958	100.881	145.674	68.646
1984	146.952	102.846	142.885	69.986

[a]Dollars per unit of foreign currency expressed as index with 1971 base.

[b]CPI of US divided by CPI of foreign country.

NETHERLANDS

YEAR	e[a]	CPIUS/CPI[b]	Real e (1)/(2)	Real E (2)/(1)
1970	96.636	102.996	93.826	106.581
1971	100.000	100.000	100.000	100.000
1972	109.001	95.761	113.826	87.853
1973	125.772	94.282	133.400	74.963
1974	130.309	95.428	136.552	73.232
1975	138.653	94.282	147.062	67.998
1976	132.442	91.682	144.458	69.224
1977	142.596	91.758	155.404	64.348
1978	161.998	94.830	170.831	58.538
1979	174.469	101.263	172.293	58.041
1980	176.211	107.882	163.337	61.223
1981	140.864	111.580	126.244	79.211
1982	131.010	111.435	117.566	85.058
1983	122.569	111.869	109.565	91.270
1984	109.024	113.010	96.473	103.656

[a]Dollars per unit of foreign currency expressed as index with 1971 base.

[b]CPI of US divided by CPI of foreign country.

SWEDEN

YEAR	e[a]	CPIUS/CPI[b]	Real e (1)/(2)	Real E (2)/(1)
1970	98.880	103.047	95.956	104.214
1971	100.000	100.000	100.000	100.000
1972	107.413	97.473	110.197	90.746
1973	117.381	97.121	120.861	82.740
1974	115.388	98.008	117.733	84.938
1975	123.515	97.473	126.717	78.916
1976	117.489	93.497	125.661	79.579
1977	114.463	89.384	128.058	78.090
1978	113.307	87.445	129.575	77.175
1979	119.365	90.746	131.537	76.024
1980	121.007	90.608	133.550	74.878
1981	101.646	89.188	113.968	87.744
1982	81.420	87.167	93.407	107.059
1983	66.717	82.611	80.760	123.823
1984	61.840	79.789	77.505	129.024

[a]Dollars per unit of foreign currency expressed as index with 1971 base.

[b]CPI of US divided by CPI of foreign currency.

SWITZERLAND

YEAR	e[a]	CPIUS/CPI[b]	Real e (1)/(2)	Real E (2)/(1)
1970	94.371	102.122	92.411	108.212
1971	100.000	100.000	100.000	100.000
1972	108.065	96.875	111.551	89.645
1973	130.951	94.663	138.333	72.289
1974	139.035	95.679	145.314	68.816
1975	160.037	97.872	163.516	61.156
1976	165.164	101.818	162.215	61.647
1977	172.346	106.778	161.405	61.956
1978	232.487	113.949	204.027	49.013
1979	248.322	122.477	202.751	49.322
1980	246.597	133.550	184.648	54.157
1981	210.858	138.414	152.339	65.643
1982	203.261	139.163	146.059	68.465
1983	196.599	139.462	140.969	70.938
1984	175.631	141.355	124.248	80.484

[a]Dollars per unit of foreign currency expressed as index with 1971 base.

[b]CPI of US divided by CPI of foreign country.

UNITED KINGDOM

YEAR	e[a]	CPIUS/CPI[b]	Real e (1)/(2)	Real E (2)/(1)
1970	98.587	104.899	93.983	106.402
1971	100.000	100.000	100.000	100.000
1972	102.770	96.339	106.676	93.742
1973	100.730	93.855	107.326	93.174
1974	96.083	89.730	107.081	93.388
1975	91.268	78.856	115.739	86.401
1976	74.196	71.614	103.605	96.520
1977	71.702	65.830	108.919	91.811
1978	78.849	65.372	120.616	82.908
1979	87.149	64.160	135.831	73.621
1980	95.559	61.722	154.821	64.591
1981	83.303	60.908	136.767	73.117
1982	71.907	59.457	120.939	82.686
1983	62.315	58.690	106.176	94.183
1984	54.893	58.319	94.124	106.243

[a]Dollars per unit of foreign currency expressed as index with 1971 base.

[b]CPI of US divided by CPI of foreign country.

Appendix Table 2. Weights for computing IMF MERM and Federal Reserve Board effective exchange rates

COUNTRY	FRB WEIGHTS	MERM WEIGHTS
JAPAN	0.2125	0.1360
CANADA	0.2028	0.0910
GERMANY	0.1302	0.2080
FRANCE	0.1011	0.1310
ITALY	0.0747	0.0900
UNITED KINGDOM	0.0506	0.1190
AUSTRALIA	0.0486	.
NETHERLANDS	0.0324	0.0830
SWEDEN	0.0273	0.0420
BELGIUM	0.0244	0.0640
SPAIN	0.0244	.
SWITZERLAND	0.0169	0.0360
DENMARK	0.0140	.
NORWAY	0.0121	.
AUSTRIA	0.0113	.
FINLAND	0.0111	.
IRELAND	0.0058	.

Appendix Table 3. Nominal effective exchange rates based on 1976-78 U.S. agricultural export weights

YEAR	ARITH	INV ARITH	GEOM	INV GEOM
1970	101.2	101.1	101.1	101.2
1971	100.0	100.0	100.0	100.0
1972	94.6	94.2	94.3	94.4
1973	88.3	86.8	87.6	87.5
1974	89.9	88.3	89.1	89.1
1975	91.2	87.9	89.5	89.4
1976	97.4	92.1	94.6	94.4
1977	100.0	90.4	94.6	94.6
1978	96.4	80.6	87.3	87.1
1979	99.9	79.5	87.2	87.1
1980	110.0	80.0	89.1	89.0
1981	135.3	89.9	101.2	100.9
1982	183.5	100.1	115.9	116.0
1983	337.5	104.0	128.3	128.6
1984	755.8	111.4	143.2	145.8

Appendix Table 4. Nominal effective exchange rates based on 1976-78 global agricultural export weights

YEAR	ARITH	INV ARITH	GEOM	INV GEOM
1970	99.0	98.4	98.7	98.7
1971	100.0	100.0	100.0	100.0
1972	99.9	97.8	98.7	98.7
1973	94.4	89.6	91.7	91.5
1974	95.4	90.5	92.6	92.7
1975	125.7	90.8	99.4	96.9
1976	243.0	99.1	115.7	115.3
1977	526.1	99.5	124.6	124.3
1978	929.5	92.7	123.8	123.7
1979	1479.8	89.1	126.5	126.1
1980	2058.5	89.5	136.3	136.8
1981	4786.7	106.6	171.6	168.4
1982	27483.8	121.1	221.7	222.1
1983	111088.3	132.8	284.9	285.3
1984	710381.1	144.7	375.8	364.9

Appendix Table 5. Real effective exchange rates based on 1976-78 U.S. agricultural export weights

YEAR	ARITH	INV ARITH	GEOM	INV GEOM
1970	103.2	103.2	103.2	103.2
1971	100.0	100.0	100.0	100.0
1972	92.0	91.8	91.9	91.9
1973	83.4	82.0	82.7	82.6
1974	79.8	78.6	79.2	79.2
1975	77.5	75.9	76.7	76.7
1976	78.6	76.3	77.6	77.4
1977	75.9	72.7	74.3	74.2
1978	70.5	65.6	68.1	67.9
1979	71.5	67.0	69.1	69.0
1980	72.7	68.6	70.5	70.4
1981	80.4	76.5	78.5	78.3
1982	88.0	84.4	86.2	86.3
1983	91.8	87.5	90.1	90.1
1984	96.1	96.4	98.8	98.8

Appendix Table 6. Real effective exchange rates based on 1976-78 global agricultural export weights

YEAR	ARITH	INV ARITH	GEOM	INV GEOM
1970	102.6	102.4	102.6	102.5
1971	100.0	100.0	100.0	100.0
1972	93.5	93.1	93.2	93.3
1973	82.7	81.7	82.2	82.1
1974	80.0	79.2	79.6	79.6
1975	79.7	76.1	78.7	76.7
1976	81.1	79.3	80.3	80.0
1977	79.5	77.4	78.5	78.4
1978	74.0	71.7	72.9	72.8
1979	72.3	69.2	70.8	70.6
1980	74.2	70.5	72.0	72.3
1981	84.5	80.2	83.4	81.9
1982	95.2	93.7	94.4	94.5
1983	103.3	101.0	102.0	102.1
1984	111.3	110.3	111.3	111.6

Appendix Table 7. Real effective exchange rates based on 1976-78 U.S. soybean export weights

YEAR	ARITH	INV ARITH	GEOM	INV GEOM
1970	104.3	104.3	104.2	104.3
1971	100.0	100.0	100.0	100.0
1972	89.7	89.6	89.6	89.7
1973	79.0	78.1	78.6	78.5
1974	75.8	75.1	75.4	75.4
1975	72.5	71.8	72.2	72.1
1976	74.5	73.3	73.9	73.8
1977	71.1	69.2	70.1	70.0
1978	64.3	61.4	62.8	62.7
1979	63.6	61.7	62.6	62.6
1980	65.0	63.6	64.3	64.2
1981	76.6	74.5	75.6	75.4
1982	85.6	83.8	84.6	84.7
1983	90.7	88.0	89.3	89.4
1984	98.1	94.4	96.3	96.3

Appendix Table 8. Real effective exchange rates based on 1976-78 global soybean export weights

YEAR	ARITH	INV ARITH	GEOM	INV GEOM
1970	101.8	101.9	101.8	101.9
1971	100.0	100.0	100.0	100.0
1972	99.2	98.8	98.9	99.0
1973	91.9	91.2	91.5	91.7
1974	87.8	86.9	87.3	87.4
1975	92.5	85.9	91.6	86.7
1976	88.2	86.5	87.7	86.9
1977	87.3	85.4	86.6	86.1
1978	83.0	81.3	82.1	82.5
1979	86.0	80.1	83.7	82.7
1980	100.3	89.0	94.6	95.0
1981	100.9	88.2	98.4	93.0
1982	112.4	111.5	111.8	112.2
1983	143.0	137.1	140.0	140.5
1984	160.7	154.0	157.3	157.8

Appendix Table 9. Real effective exchange rates based on 1976-78 U.S. wheat export weights

YEAR	ARITH	INV ARITH	GEOM	INV GEOM
1970	101.5	101.3	101.4	101.4
1971	100.0	100.0	100.0	100.0
1972	94.3	94.0	94.1	94.2
1973	87.1	85.6	86.4	86.4
1974	82.0	80.6	81.3	81.3
1975	80.4	78.4	79.4	79.4
1976	80.7	77.3	79.1	78.9
1977	76.9	72.8	74.9	74.8
1978	72.7	66.9	69.8	69.7
1979	74.3	69.2	71.7	71.6
1980	76.4	70.8	73.5	73.4
1981	79.3	73.8	76.6	76.2
1982	85.6	79.8	82.7	82.7
1983	89.7	82.9	88.2	87.9
1984	92.5	99.8	103.6	104.4

Appendix Table 10. Real effective exchange rates based on 1976-78 global wheat export weights

YEAR	ARITH	INV ARITH	GEOM	INV GEOM
1970	102.8	102.8	102.8	102.8
1971	100.0	100.0	100.0	100.0
1972	96.2	95.7	95.9	96.0
1973	86.2	85.1	85.6	85.7
1974	83.6	82.5	83.0	83.1
1975	88.4	81.3	87.1	82.1
1976	84.1	82.8	83.7	83.2
1977	88.7	87.1	88.1	87.7
1978	86.3	83.4	84.9	84.7
1979	85.9	80.1	83.3	82.9
1980	86.1	79.3	82.1	83.1
1981	91.1	81.5	88.7	85.9
1982	102.0	100.6	101.2	101.4
1983	102.5	102.2	102.3	102.5
1984	106.0	105.4	105.6	105.8

Appendix Table 11. Real effective exchange rates based on 1976-78 U.S. cotton export weights

YEAR	ARITH	INV ARITH	GEOM	INV GEOM
1970	100.5	100.5	100.4	100.6
1971	100.0	100.0	100.0	100.0
1972	95.5	94.7	95.0	95.2
1973	88.8	86.2	87.5	87.6
1974	80.1	77.3	78.8	78.8
1975	81.3	78.2	79.8	79.8
1976	80.2	77.6	78.9	79.0
1977	76.9	73.1	75.1	75.1
1978	71.7	66.0	69.2	69.0
1979	73.6	69.4	71.4	71.5
1980	75.2	70.5	72.9	72.9
1981	79.1	72.9	76.7	76.7
1982	86.0	79.3	83.8	84.0
1983	89.3	78.3	86.6	86.8
1984	93.4	90.5	92.2	92.4

Appendix Table 12. Real effective exchange rates based on 1976-78 global cotton export weights

YEAR	ARITH	INV ARITH	GEOM	INV GEOM
1970	96.0	94.1	96.2	94.5
1971	100.0	100.0	100.0	100.0
1972	101.3	97.7	99.6	98.5
1973	93.8	90.5	92.6	91.8
1974	86.3	83.6	86.1	84.8
1975	81.6	78.9	81.8	81.8
1976	82.3	79.3	82.6	82.0
1977	80.3	76.4	80.0	80.0
1978	78.6	74.8	78.6	78.4
1979	84.9	75.8	81.9	81.4
1980	87.2	80.4	85.2	84.7
1981	88.5	80.8	86.2	84.1
1982	109.0	99.7	104.8	104.8
1983	114.9	104.6	110.3	110.3
1984	50.8	117.7	107.9	120.3

Appendix Table 13. Real effective exchange rates based on 1976-78 U.S. corn export weights

YEAR	ARITH	INV ARITH	GEOM	INV GEOM
1970	103.8	103.8	103.8	103.9
1971	100.0	100.0	100.0	100.0
1972	91.0	90.7	90.8	90.9
1973	81.5	80.3	81.0	80.8
1974	77.9	77.0	77.4	77.4
1975	75.5	74.5	75.0	74.9
1976	77.8	76.0	77.0	76.7
1977	74.6	72.1	73.3	73.3
1978	67.9	64.0	66.0	65.8
1979	68.1	65.0	66.4	66.4
1980	69.2	66.7	67.9	67.8
1981	78.9	75.9	77.4	77.2
1982	88.5	85.9	87.1	87.2
1983	93.9	89.9	91.9	91.9
1984	100.5	95.9	98.5	98.5

Appendix Table 14. Real effective exchange rates based on 1976-78 global corn export weights

YEAR	ARITH	INV ARITH	GEOM	INV GEOM
1970	103.1	103.2	103.0	103.2
1971	100.0	100.0	100.0	100.0
1972	102.1	100.9	101.5	101.5
1973	85.8	85.4	85.5	85.7
1974	79.5	79.4	79.3	79.6
1975	93.0	76.1	90.8	76.6
1976	85.6	82.9	84.9	83.5
1977	87.4	84.0	86.2	85.0
1978	77.0	74.7	76.1	75.6
1979	69.2	64.6	67.3	66.5
1980	65.7	62.1	62.4	64.4
1981	76.4	63.7	74.4	67.8
1982	104.5	103.1	103.5	104.1
1983	105.1	103.5	103.9	104.5
1984	117.7	115.8	116.3	117.0

Appendix Table 15. Nominal effective exchange rates chain link index based on U.S. agricultural exports

YEAR	ARITH	INV ARITH	GEOM	INV GEOM
1970	100.0	100.0	100.0	100.0
1971	98.9	98.7	98.8	98.8
1972	94.2	93.6	93.9	93.9
1973	88.3	87.1	87.7	87.6
1974	90.3	89.0	89.7	89.7
1975	91.5	89.5	90.5	90.4
1976	97.9	94.9	96.5	96.2
1977	98.3	94.2	96.3	96.1
1978	91.6	86.3	89.0	88.6
1979	93.4	86.6	89.8	89.6
1980	103.4	91.7	97.0	96.8
1981	118.3	103.0	110.0	109.5
1982	144.3	120.2	130.6	130.4
1983	169.2	133.1	147.9	147.8
1984	197.0	148.3	167.5	167.3

Appendix Table 16. Real effective exchange rates chain link index based on U.S. agricultural exports

YEAR	ARITH	INV ARITH	GEOM	INV GEOM
1970	100.0	100.0	100.0	100.0
1971	97.2	97.1	97.1	97.1
1972	90.0	89.6	89.8	89.9
1973	81.5	80.5	81.0	80.9
1974	78.0	76.7	77.4	77.4
1975	76.2	74.6	75.5	75.4
1976	78.7	76.3	77.6	77.4
1977	75.4	72.8	74.2	74.0
1978	69.5	66.5	68.2	67.9
1979	71.6	67.6	69.6	69.4
1980	74.2	69.3	71.8	71.6
1981	82.0	75.4	78.8	78.4
1982	91.9	83.7	87.7	87.6
1983	96.7	87.5	92.0	91.9
1984	102.4	91.8	96.9	96.8

Appendix Table 17. Nominal effective exchange rates based on 1981-83 U.S. agricultural exports

YEAR	ARITH	INV ARITH	GEOM	INV GEOM
1970	100.5	100.4	100.4	100.5
1971	100.0	100.0	100.0	100.0
1972	95.4	94.9	95.1	95.2
1973	89.7	88.1	88.9	88.8
1974	91.2	89.5	90.4	90.4
1975	93.3	89.7	91.4	91.4
1976	100.1	94.2	97.0	96.6
1977	105.2	93.8	98.8	98.7
1978	103.8	84.5	92.5	92.3
1979	110.8	84.5	94.3	94.2
1980	124.4	85.3	97.2	97.1
1981	154.4	94.9	109.7	109.4
1982	220.2	106.6	128.7	128.8
1983	433.4	111.3	147.4	147.5
1984	992.7	119.0	168.2	168.4

Appendix Table 18. Real effective exchange rates based on 1981-83 U.S. agricultural exports

YEAR	ARITH	INV ARITH	GEOM	INV GEOM
1970	102.7	102.6	102.6	102.7
1971	100.0	100.0	100.0	100.0
1972	92.6	92.3	92.4	92.5
1973	84.4	82.8	83.6	83.5
1974	79.8	78.4	79.1	79.1
1975	77.7	75.8	76.7	76.7
1976	78.6	76.0	77.5	77.1
1977	76.6	72.9	74.8	74.7
1978	71.6	66.2	68.9	68.7
1979	73.5	68.0	70.6	70.5
1980	74.3	69.5	71.8	71.7
1981	80.6	75.9	78.4	78.2
1982	89.1	84.7	87.0	87.1
1983	93.8	87.5	91.1	91.2
1984	101.1	96.4	98.7	98.8

Appendix Table 19. OECD and U.S. Treasury trade-weighted dollars

Year	OECD[a] (1970Q1 = 100)	U.S. Treasury[b] Currencies of 22 OECD Countries (Percent appreciation from May 1970)	Countries
1970	99.2		
1971	96.7		
1972	90.8		
1973	83.6		
1974	84.6	-16.0	-9.6
1975	84.0	-10.9	-4.6
1976	87.6	-10.3	-1.0
1977	87.0	-14.6	-1.0
1978	79.2	-21.5	+4.1
1979	77.1	-18.4	+6.6
1980	77.1	-15.0	+21.3
1981	87.0	- 3.4	+58.9
1982	96.0	+ 9.2	+141.2
1983	105.2	+21.8	+446.4
1984		+39.9	+1736.6

[a] Source: OECD *Economic Outlook*, December 1984.

[b] Source: *Treasury Bulletin*, 1985 First Quarter.

Appendix Table 20. Effect of a 1 percent dollar appreciation in terms of the Chambers-Just Model.

	Short-run	Long-run
Prices		
Wheat	-1.242	-.790%
Corn	-1.903	-1.377
Soybeans	-2.643	-2.165
Exports		
Wheat	-1.829	-1.477
Corn	-4.072	-3.447
Soybeans	-.776	-.671
Inventories		
Wheat	.307	.125
Corn	.328	.140
Soybeans	.088	.038

Source: Robert G. Chambers and Richard E. Just. "Effects of Exchange Rate Changes on U.S. Agriculture: A Dynamic Analysis". American journal of Agricultural Economics 63 (February 1981): p. 44.

Appendix Table 21. Selected real effective exchange rates expressed as value of dollar 1970-1984

YEAR	FRB	MGT	SDR	MERM	USDA
1970	104.4	101.8	102.3	103.8	103.2
1971	100.0	100.0	100.0	100.0	100.0
1972	90.1	92.0	94.7	90.6	92.0
1973	80.1	80.3	88.9	81.1	83.4
1974	80.3	77.8	89.3	80.2	79.8
1975	75.9	80.9	86.1	77.5	77.5
1976	78.8	83.0	88.7	78.7	78.6
1977	75.6	82.3	86.2	76.4	75.9
1978	68.3	77.4	79.9	70.2	70.5
1979	67.5	77.1	78.8	71.0	71.5
1980	68.8	78.2	78.4	73.1	72.7
1981	81.7	88.0	85.9	82.7	80.4
1982	90.8	96.1	92.1	90.5	88.0
1983	95.8	98.5	95.3	93.5	91.8
1984	104.7	103.3	100.0	99.3	96.1

Appendix B

Notes on Data and Data Use

Most of the data used in the study are from the I.M.F.'s International Financial Statistics. Exchange rates were either the rh or rf series (period averages). CPI data were from line 64. MERM and SDR nominal exchange rate series were taken from the U.S. portion of the statistics. The FRB nominal index was taken from the Federal Reserve Bulletin; the Morgan Guaranty Trust real and nominal series are from MGT's publication World Financial Markets. The OECD series is from the OECD Publication Economic Outlook. The Treasury Department series is from the Treasury Bulletin. Data for Taiwan have been removed from the I.F.S. However, they are available in Financial Statistics, published by the Central Bank of China (Taiwan) and intended to fill in the reporting gap left by the I.M.F. Exchange rate series from the USDA were employed in Figures 2 and 3. Other figures reflect series constructed using individual exchange rates and the weights described below.

Weights for construction of agricultural effective exchange rates came either from the USDA (for U.S. export-weighted series using 1976-78 weights), from export data in various volumes of Foreign Agricultural Trade of the U.S. (for 1981-83 weights and for chain weights), or from FAO Trade Yearbooks (for 1976-78 global weights).

In constructing effective exchange rates, all countries were used for which requisite information was available. In some cases, data were unavailable for recent years or for other reasons. In such cases, countries were left out of the indices for certain years and weights were readjusted for those years to sum to one. Most of those cases occurred in 1983 or 1984. However, Bangladesh was missing from the U.S. export-weighted series for 1970 because the country was not yet independent. Nicaragua was left out of the global weight index for cotton because CPI data were missing for the base year (1971).

All rates were computed using annual data, and are presented in annual form.

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