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Consumption Smoothing and Exchange Rate Volatility

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Abstract

This paper analyzes exchange rate behavior in a model where consumers trade goods to diversify shocks to their income. A model with traded and nontraded goods is simulated in a multilateral context based upon historical output correlations for the period 1970-92. Simulation results indicate that the observed volatility of multilateral real exchange rates for the United States, Germany and Japan is not inconsistent with exchange rate volatility implied by consumption-smoothing behavior.

JEL Classification Numbers:

F31, F41, F47

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Summary

In a world where consumers diversify idiosyncratic shocks to their income by trading internationally, consumption is perfectly correlated across countries, and its variation over time derives entirely from aggregate shocks to the world economy. This tight link between consumption patterns across countries breaks down when there are nontradables in consumption baskets and when there are frictions in international capital markets.

This paper presents an infinite-horizon two-country model with tradable and nontradable goods in the consumption basket. Equity claims cannot be traded internationally to finance trade in goods, and countries can only adjust their stock of net foreign assets by issuing or buying short-term real bonds. When output shocks in the tradable and nontradable sectors are imperfectly correlated within a country, the price of nontradables will adjust to restore equilibrium. When output shocks are imperfectly correlated across countries, prices of nontradables adjust differently in each country, and the real exchange rate changes to induce consumption smoothing through international trade. Hence, this model provides a natural framework to answer the question of what degree of exchange rate volatility is implied by international risk sharing.

The simulation results obtained in the paper for the United States, Japan, and Germany during the post-Bretton Woods period indicate that the path of the exchange rate consistent with the trade flows necessary to induce consumption smoothing is more volatile than the benchmark multilateral real exchange rates during 1970-92 for those countries.

I. Introduction

Since the breakdown of the Bretton Woods system industrialized countries have experienced pronounced swings in their nominal exchange rates. Combined with price levels that exhibited far less volatility, these swings resulted in sharp fluctuations in real exchange rates. As these movements do not seem to be entirely related to underlying fundamental developments in the world economy, recent research in empirical international finance has focused on developing models consistent with observed exchange rate movements. 1/

Specifically, there has been a renewed interest in characterizing exchange rate behavior in fully specified general equilibrium models. In this class of models, consumers optimize consumption over an infinite horizon subject to a period-by-period budget constraint. Depending on the setup, consumers either receive resources from their endowments and their claims on future endowments or receive labor and dividend income from an explicitly modeled production sector. Bayoumi and MacDonald (1994), Bayoumi and Klein (1995), Ostry (1987), Bekaert (1994), Asea and Mendoza (1995), Baxter and Crucini (1993), and Backus and Smith (1993), adapt this basic framework to study a variety of problems concerning savings, exchange rates and current accounts. 2/

This paper contributes to this literature by attempting to answer the question what level of volatility of the exchange rate is to be expected in a world where the exchange rate works as an adjustment mechanism to smooth consumption by trading internationally to insure against country-specific income shocks. In this setup, a set of endogenous variables (such as

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1/ For instance, Bayoumi, Clark, Symansky, and Taylor (1994), analyze the fundamental equilibrium exchange rate in a macro-balance framework. In particular, the equilibrium exchange rate in their approach is viewed as the rate consistent with internal and external balance. The path for the equilibrium exchange rate is then calculated as that exchange rate consistent with an adjustment of the current account that will lead to this desirable net foreign asset position, in a manner consistent with internal balance.

2/ Faruqee (1995), MacDonald (1995), and Stein (1995), in contrast, develop models based upon a specification of the balance-of-payments which is then taken to the data using cointegration techniques. Faruqee (1995), finds strong evidence that trend variation in the real exchange rate is to a large extent driven by differential productivity growth for the United States and Japan. MacDonald (1995), also uses cointegration techniques to test his "Eclectic Exchange Rate Model" for nominal exchange rates and finds that his model performs reasonably well for the U.S. dollar and the Japanese yen. Stein (1995), develops a NATREX model (standing for NATural Real Exchange rate) based upon trend movements in fundamentals (e.g., without cyclical movements) and nonspeculative capital flows.

prices, interest rates, exchange rates, and the current account) are jointly determined by changes in the production environment and consumer's preferences but have until recently required the use of a set of simplifying assumptions of which some are clearly at odds with observed economic behavior.

This paper attempts to make three contributions in this general-equilibrium set-up. First, it analyzes the joint behavior of real exchange rates, the current account and net foreign asset positions. Although there is an extensive literature on the role of current account and the exchange rate, few attempts have been made to integrate both in a formal model of the world economy. Broadly, two characteristics can be discerned in the literature on this subject. With a few exceptions such as Tesar (1990), Asea and Mendoza (1995), Micossi and Milesi-Feretti (1994), and de Gregorio, Giovannini and Wolf (1994), most models incorporate only one good. For example, Baxter and Crucini (1993), analyze savings and investment correlations in a model with one good. Whereas such a framework is adequate to analyze the role of the current account in the transmission of shocks internationally, there is, per definition, no role for exchange rates.

Second, this paper does not impose complete international risk sharing, a hypothesis usually maintained in the literature. This hypothesis typically takes one of two forms. One approach assumes that agents across countries are identical in all respects; their preferences are governed by the same parameters and their asset holdings are constant over time. Such a set-up has been used extensively to analyze long-run behavior of a variety of asset prices such as real exchange rates (Asea and Mendoza (1995)), or interest rates and nominal exchange rates (Bekaert (1994)). This class of models is ill-suited to characterize the behavior of the current account since it puts very strong restrictions on the trade balance and net foreign asset position. Alternatively, this condition of perfect risk pooling is imposed by a social planner who maximizes the joint welfare of residents in both countries e.g., Backus and Smith (1993), Baxter and Crucini (1993), and Tesar (1990). 1/ In contrast to previous empirical work in this area no restrictions are placed on the distribution of net foreign assets over time in this paper. Hence, the theoretical model in this paper is potentially consistent with a rich menu of different asset holdings across countries. It is thus possible to study the joint determination of the current account, net foreign assets and the real exchange rate in a more realistic manner. In order to do this, the paper introduces a solution method, based upon polynomials to parametrize expectations, that so far has only been applied in a domestic country context.

1/ A non-zero current account can be obtained by allowing consumption parameters to vary across countries, e.g., different rates of time preference can result in a non-zero current account in the steady state. Hence, swings in the current account result from relative changes in the rates of time preferences over time.

Finally, the paper addresses these issues in a multilateral context. Although the current account, the difference between savings and investment, and net foreign assets are inherently multilateral phenomena, previous empirical work often analyzes these and related issues in a bilateral context. In contrast, this paper provides three sets of simulation results with the United States, Japan and Germany as reference countries where ten industrialized countries constitute the rest of the world. Hence, the role of real effective exchange rates can be clearly analyzed. 1/

In order to accomplish this, a quantitatively restricted general equilibrium model is developed in the paper. The model encompasses two countries, a reference country and the rest-of-the-world. Both economies are endowment economies--there is no production sector--and residents in each country receive endowments of tradables and nontradables in every period. The absence of frictions in international trade results in PPP holding for tradable goods. However, imperfect correlation of endowment shocks of tradables and nontradables across countries and over time lead to different real interest rates across countries and a time-varying real exchange rate. As will be shown in section III, this leads to a natural setup to analyze exchange rate and current account volatility.

It is important to mention some of the limitations of this exercise. Neither a government sector nor a production sector has been explicitly modeled. The absence of a government sector obviously prevents an analysis of the effects of differences in tax and expenditure policies across countries. Similarly, the exclusion of a production sector precludes a study of movements in fixed investment over time and across countries. It is important, however, to note that, to the extent that the observed consumption and endowment patterns are affected by changes in government policy and productivity differentials these two factors are indirectly incorporated in the model. 2/

In addition, all endogenous variables are functions of stationary output variables. This is a particularly important constraint for open economy models since it requires, in a loose sense, similar growth rates in different countries. We follow the literature in this respect and detrend output variables in our empirical work. 3/ Hence, this approach can, per definition, not generate trend movements in real exchange rates or any of

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1/ Using a completely different methodology, Faruqee (1995), and MacDonald (1995b), also looks at multilateral exchange rates.

2/ Adding a government sector and explicitly modeling a production sector adds a layer of complexity to the solution of the model. Both extensions would imply incorporating multiple equity claims and bonds potentially denominated in different goods in the model which raises the complexity of simulating the model considerably. For attempts to do so in a simpler set-up, see Mendoza and Tesar (1993), and Baxter and Crucini (1993).

3/ The issue of detrending is taken up in section III.

the other endogenous variables and is ill-suited to analyze long-term trend movements in real exchange rates. 1/

The paper is organized as follows. The next section presents the empirical evidence on real effective exchange rates, trade balances and net foreign asset positions for the United States, Germany and Japan, the "home" countries in the three simulation exercises. Section III develops the model and lays out the solution technique. The simulation results for real exchange rates, real interest rates, consumption correlations and the external position are reported in Section IV. Section V concludes the paper.

II. Empirical Evidence on the External Variables for the United States, Japan and Germany

Given our goal of constructing and testing a model to explain co-movements in real effective exchange rates, the trade balance and the net foreign asset position of the United States, Japan and Germany, this section reviews the evolution of these key variables in the post-war period. All variables have the conventional definitions. The real effective exchange rates are taken from IFS, with an increase reflecting an appreciation. The trade balance is the difference between exports and imports of goods and services as a percentage of GNP. The stock of net foreign assets adds the trade balance to the stock of net foreign assets in the previous period, the latter including interest payments. 2/

Charts 1 through 3 summarize the evolution of the trade balance, the net foreign asset position and the real effective exchange rate for the United States, Japan and Germany. Since these episodes have been discussed extensively elsewhere, a brief overview suffices to illustrate the movements of these variables in those countries.

Chart 1 reports the time series for the real effective exchange rate, the trade balance and the net foreign asset position for the United States. The top panel of Chart 1 shows the secular decline in the value of the U.S. dollar measured (in log levels) in real effective terms. This decline had

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1/ This problem is not unique to this class of models and is empirically only relevant for extremely long sample periods that are not available. It is by now common wisdom that a significant component of the trend movement in the yen exchange rate is driven by productivity differentials. Obviously, if such differentials would persist forever, all other countries would vanish relative to the Japanese economy.

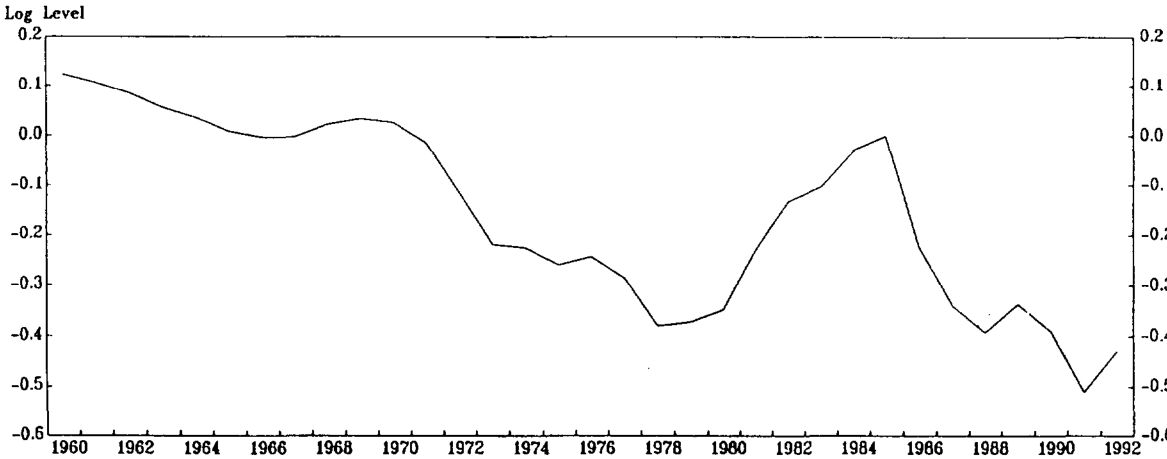
2/ Strictly speaking, this is only correct if there has been no changes in nominal exchange rates that affect the valuation of the assets and liabilities in the net foreign asset position. To the extent that there are exchange rate changes, a valuation effect should be added to the right-hand side of the net foreign asset equation. The data on net foreign assets take this valuation effect into account.

CHART 1.

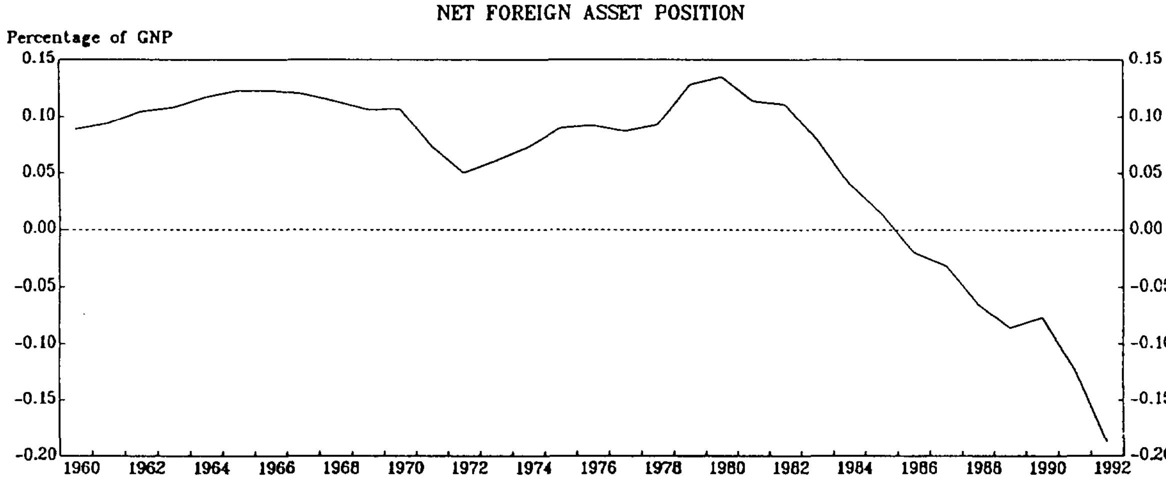
UNITED STATES

REAL EFFECTIVE EXCHANGE RATE, NET FOREIGN ASSETS AND TRADE BALANCE

REAL EFFECTIVE EXCHANGE RATE



NET FOREIGN ASSET POSITION



TRADE BALANCE

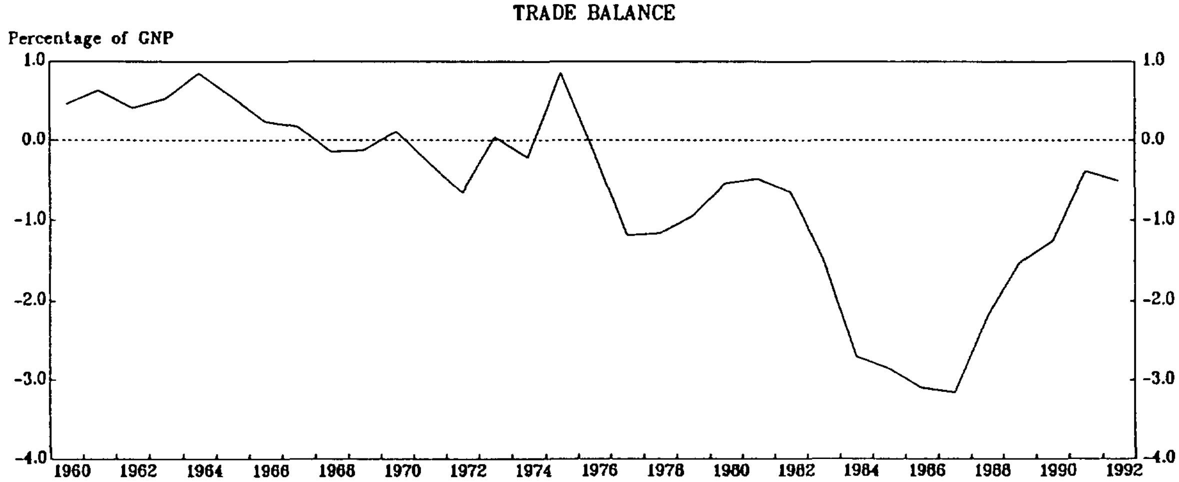
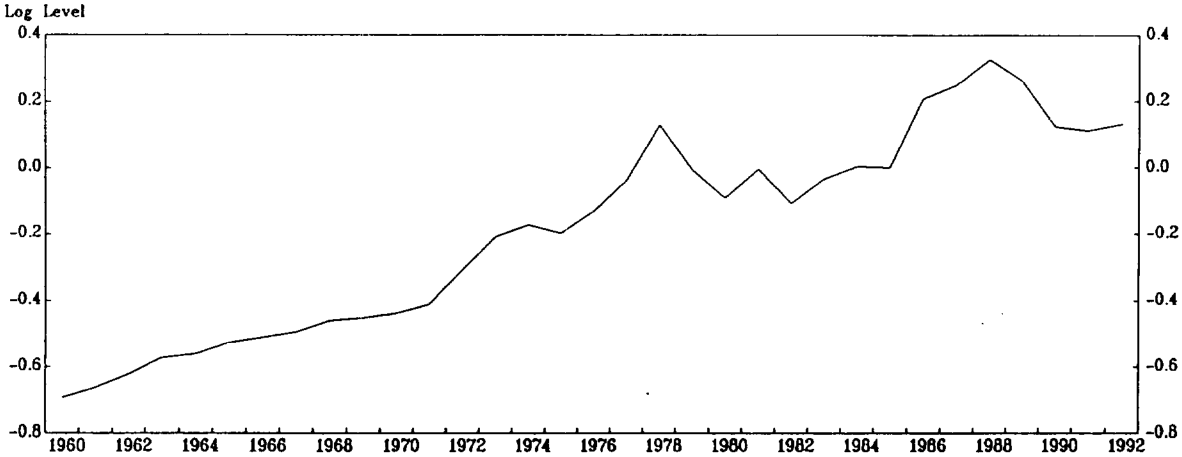


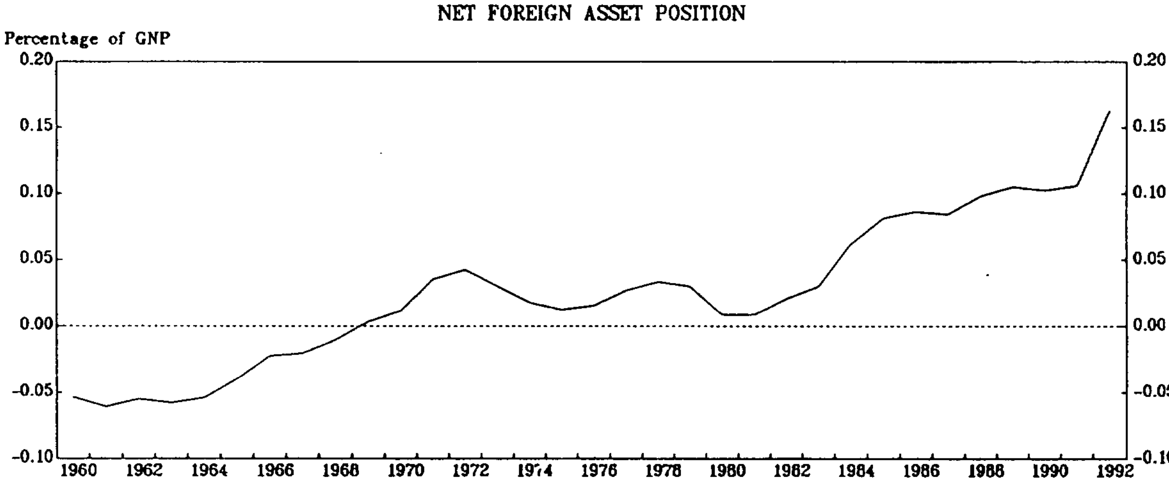
CHART 2.

JAPAN
REAL EFFECTIVE EXCHANGE RATE, NET FOREIGN ASSETS AND TRADE BALANCE

REAL EFFECTIVE EXCHANGE RATE



NET FOREIGN ASSET POSITION



TRADE BALANCE

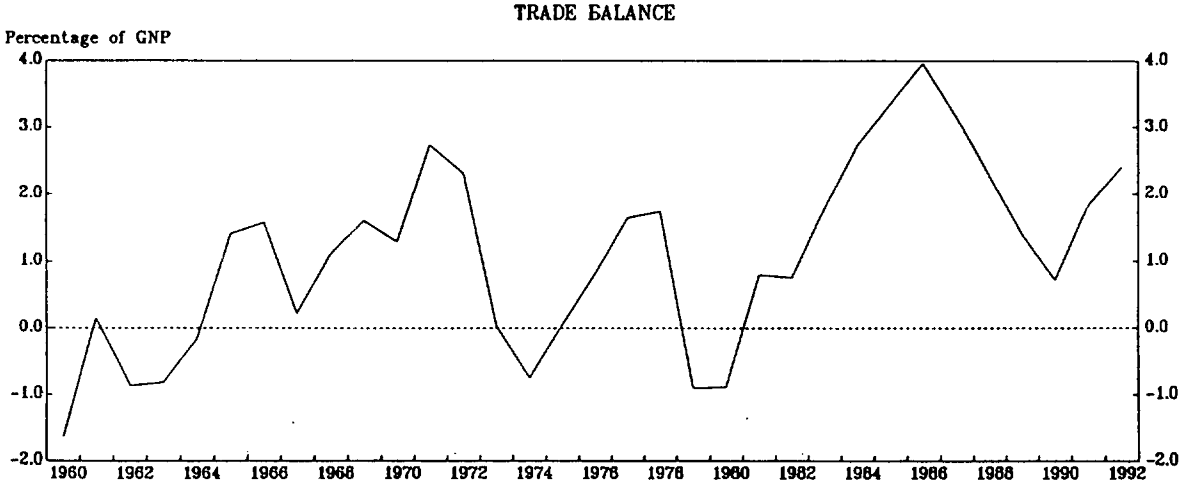
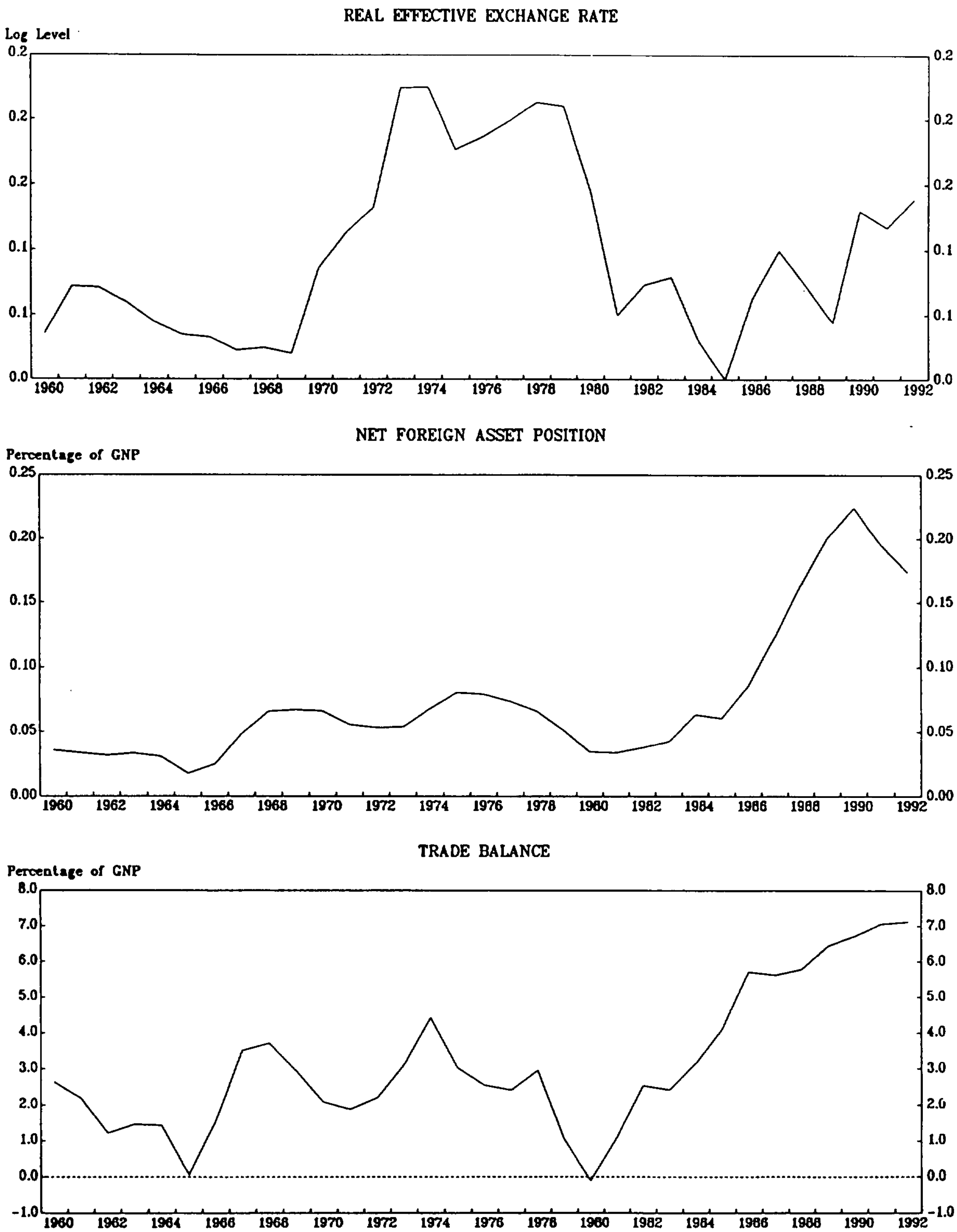


CHART 3.

GERMANY

REAL EFFECTIVE EXCHANGE RATE, NET FOREIGN ASSETS AND TRADE BALANCE



already started during the Bretton Woods period but accelerated dramatically during the 1970s. The tight monetary policy, combined with a loose fiscal policy, led to a sharp appreciation of the U.S. dollar in the first half of the 1980s. This improvement proved only temporary: in the face of large current account deficit, the dollar declined further from 1986 onwards. The middle panel in Chart 1 shows the corresponding trade balance movements as a percentage of GNP. By the end of the 1970s, the U.S. trade balance has slipped into a significant deficit, a trend which remains unreversed up to this date but peaking in 1987. Panel C of chart 1 shows the net foreign asset position as a percentage of GNP. Not surprisingly, this measure exhibits a similar decline in the 1980s. During the 1970s, the U.S. net foreign asset position improved slightly but worsened sharply afterwards turning negative in 1985.

Chart 2 presents similar evidence for Japan. These three variables are almost mirror images of the U.S. time series. The real effective exchange rate (panel A) has been appreciating steadily since the beginning of the sample period. Although Japan was running a trade balance deficit until 1964, exports of goods and services exceeded imports throughout the rest of the sample period except during the two oil price shocks. Especially during the first half of the 1980s there was a significant buildup in the trade balance which declined quite strongly afterwards but remained positive. Not surprisingly, the net foreign asset position corresponds with the evolution in Japan's external position. Although Japan was initially a net debtor to the rest-of-the-world, it has been building up net foreign asset positions continuously reaching around 16 percent of GNP in 1992.

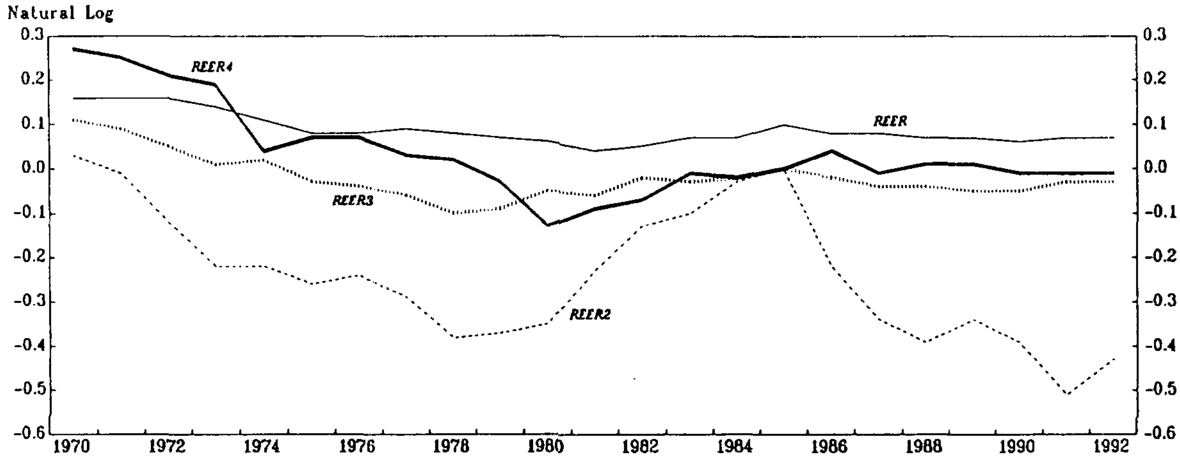
The German trade and net foreign asset position, pictured in chart 3, reflect the Japanese pattern although the evolution of the real exchange rate has been more complicated. The DM was, on a real effective basis, rather stable during the 1960s exhibiting a slight depreciation. During the 1970s, the DM appreciated strongly but depreciated quite dramatically during the first half of the 1980s. Since 1985 the DM has again started to appreciate significantly. The trade balance has been in surplus throughout our sample period, an evolution which is reflected in the net foreign asset position. The latter was fairly stable at around 5 percent of GNP until 1985. From 1986 until 1990, the net foreign asset surplus exploded to well over 20 percent. Financing needs to rebuild East Germany reduced this position to slightly less than 18 percent in 1992.

Given the specific definition for the real effective exchange rate--based on prices for tradables and nontradables--that used in the next section, it is useful to compare some alternative measures for this variable. Chart 4 presents four different measures for the three reference countries, the United States, Japan and Germany. REER is a measure for real effective exchange rates based upon prices of tradables and nontradables which were derived from OECD sectoral data and weighted with GDP shares for

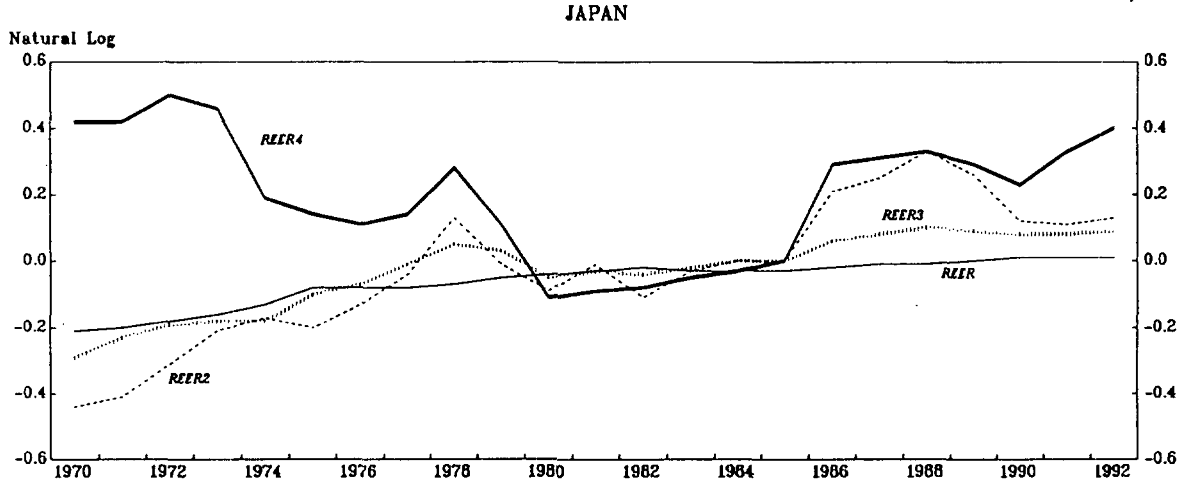
CHART 4.

MEASURES OF REAL EXCHANGE RATES

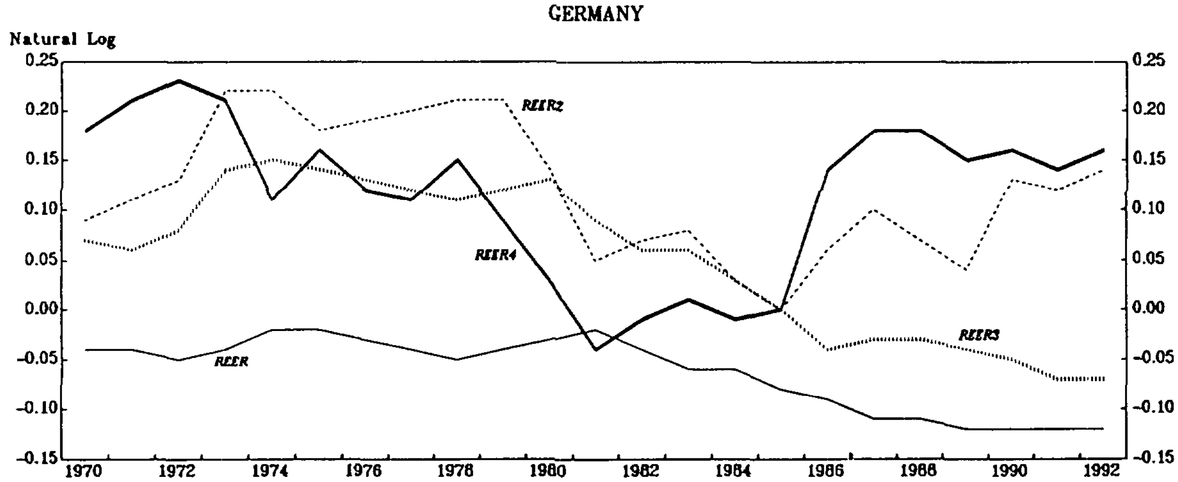
UNITED STATES



JAPAN



GERMANY



10 industrialized countries. 1/ This measure is the benchmark against which our model will be measured since its definition was most consistent with the exchange rate derived in the model. REER2 is the real effective exchange rate, as defined in International Financial Statistics (IFS), that was used in Charts 1-3. It is based upon relative normalized unit labor costs in manufacturing weighted for trade in manufactured good with a set of industrialized countries. REER3 is a similar measure where the prices of tradables and nontradables are approximated by the consumer price and a wholesale price index respectively. REER4 is a measure of the terms of trade, calculated as the ratio of export and import unit values.

The top panel provides evidence for these measures in the United States from 1970 until 1992. All measures point to similar movements except for the measure provided in IFS. Although it is beyond the scope of this paper to pinpoint the exact reasons for this deviation, the inclusion of a broader group of countries and the use of manufacturing unit labor costs are likely to be the among the most important reasons for this deviation. The use of manufacturing unit labor costs render it a quite different concept altogether. The middle panel provides similar evidence for Japan. Although the series move more closely together in this case, except for the terms of trade in the 1970s, the series do exhibit different degrees of volatility. The German data, provided in the bottom panel, point to the most striking differences in the different measures for real effective exchange rates. As has been documented extensively in Feldman (1994), inclusion of other sectors than manufacturing, seems to be driving most of the divergences in these indicators.

In the next section, we develop the model for which the simulation results are presented in section IV.

III. The Model

At this stage, we develop a fully specified general equilibrium model to capture the time series properties of the data described in the previous section. The purpose for developing such a model is to derive expressions for the exchange rate that tightly tie them to underlying fundamentals. These expressions are then used to check what time series behavior is implied for the real effective exchange rate that corresponds to the observed time series behavior for the underlying fundamentals. Hence, *equilibrium exchange rates in this context refer to exchange rates* consistent with observed fundamentals given the linkages implied by the model. As has been pointed out earlier, it is important to realize that this concept of equilibrium is different from the equilibrium concept in the macro-balance approach where an exchange rate is considered to be in

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1/ An exact definition of this variable is provided in equation (17) in section III.2. A detailed description of the breakdown of traded and nontraded sectors is provided in the appendix where plots for these variables are also provided.

equilibrium if it attains a value that corresponds to desired values for the underlying fundamentals.

The key characteristics can be described as follows. The model incorporates intertemporally optimizing behavior in an infinite horizon framework. There are two countries in the model, the reference or home country and the rest-of-the-world (from now on referred to as ROW). Residents in each country, who are identical within each country but different across countries, receive an endowment of a tradable and a nontradable good in each period. The tradable good is the same in the two countries, implying that the law of one price holds for tradable goods. 1/ Shocks to the endowments of tradable and nontradable goods are imperfectly correlated across countries. The desire on behalf of consumers to smooth their consumption drives the trade balance and the net foreign asset position in this model: the resident of the home country wants to import from the ROW when his country is hit by an adverse shock to its endowment and vice-versa. It finances these imports by issuing a one-period bond to the resident of the other country--there are no outside assets in the model. Hence, the capital account is the flip side of the current account in this model. The remainder of this section develops these ideas formally, provides the equilibrium conditions and describes the methodology to solve the model.

1. Basic structure

Households in each country i maximize a time-separable intertemporal utility function with consumption of tradable and nontradable goods as arguments. All households in each country are the same and are represented by a single, infinitely-lived agent.

$$Max E_0 \sum_{t=1}^{t=\infty} \beta^t \frac{1}{1-\gamma} [T_{i,t}^{\alpha} NT_{i,t}^{1-\alpha}]^{1-\gamma} \tag{1}$$

where $T_{t,i}$ is consumption of the tradable good and $NT_{t,i}$ is consumption of the domestic nontradable good in period t by the resident of country i. γ measures the degree of risk aversion with regard to the consumption basket of tradable and nontradable goods and is also the inverse of the coefficient of intertemporal substitution; α is the weight of the tradable good in the consumption basket and ß is the discount factor. 2/

1/ See Clark, Bartolini, Bayoumi, and Symansky (1994), and Froot and Rogoff (1995), for a recent overview of PPP and its deviations.

2/ The use of a Cobb-Douglas consumption function implies that the share of spending on tradables and nontradables is fixed. Helbling and Turtelboom (1995), reports that these results are robust to using a more general specification for the utlity function.

In every period, household i receives an endowment of the tradable good and the nontradable good produced in his home country i. The household cannot consume his own endowment but can use the proceeds from its sale to consume the tradable and nontradable good. In addition, the household can invest in a one-period bond, expressed in terms of the tradable good. Hence, household i's budget constraint, in terms of the tradable good, takes the following form:

$$T_{i,t}+p_{i,t}NT_{i,t}+q_t b_{i,t+1}\leq\bar{T}_{i,t}+p_{i,t}\bar{NT}_{i,t}+b_{i,t} \tag{2}$$

for all i - 1, ... , N and t - 1, ..., T.

$p_{i,t}$ is the price of the nontradable good in terms of the tradable good in country i in period t. q_t is the price of one unit of the one-period discount bond in period t. $b_{i,t+1}$ is the amount of the bond that the resident of country i decides to buy or sell in period t whereas $b_{i,t}$ is the stock of bonds that country i's resident carried over from period t-1. Since this is a two-country set-up, albeit in a multilateral context, with a representative agent in each country, $b_{i,t}$ corresponds to the net foreign asset position of country i. $\bar{T}_{i,t}$ and $\bar{NT}_{i,t}$ are period t's realization of the production of tradables and nontradables in country i. Hence, equation (4) states that country i's total spending on tradables, nontradables and assets cannot exceed its wealth in period t which is comprised of its endowment of tradables and nontradables plus its asset position carried over from the previous year. 1/

In addition, the following market clearing conditions need to hold in equilibrium:

$$\sum_{i=1}^{i=N}T_{i,t}=\sum_{i=1}^{i=N}\bar{T}_{i,t} \tag{3}$$

$$NT_{i,t}=\bar{NT}_{i,t} \tag{4}$$

for all i - 1, ... , N and t = 1, ..., T.

These equations summarize the physical world resource constraints. World demand for tradables has to equal world supply of tradables and, per definition, each country's consumption of nontradables cannot exceed its production.

1/ It is clear from this set-up that the goods market operates without any rigidities. Helbling and Turtelboom (1995), incorporate real rigidities in international trade in a similar setup.

$$\sum_{i=1}^{i=N} b_{i,t}=0 \tag{5}$$

Equation (5) implies that there are no "outside" assets in the world economy: bonds are in zero net supply in every period t.

2. Equilibrium outcome

In equilibrium, each agent i maximizes equation (1) subject to his budget constraint (2). In addition, the resource constraints cannot be violated for the world economy as a whole. Although the number of countries does not make it more difficult to solve the model conceptually, we solve it for the two country case. In the empirical section, the home country is the United States, Japan and Germany respectively in each of the simulation exercises. The second country is modelled as the aggregate of a set of industrial countries including Belgium, Canada, Germany, Italy, Japan, Sweden, the United Kingdom and the United States. Due to data unavailability, some G-10 countries such as France, the Netherlands and Switzerland were excluded. This "rest-of-the-world" is defined as the sum of these countries, converted into dollars at 1985 PPP rates, minus the respective reference country.

An equilibrium can now be defined as a set of prices ($p_1{}^*$, $p_2{}^*$, q^*) and quantities ($x_1{}^*$, $x_2{}^*$, $y_1{}^*$, $y_2{}^*$, $b_1{}^*$, $b_2{}^*$) for which the following system of equations holds:

$$p_{1,t}^*=\frac{1-\alpha}{\alpha}\frac{T_{1,t}^*}{NT_{1,t}^*} \tag{6}$$

$$p_{2,t}^*=\frac{1-\alpha}{\alpha}\frac{T_{2,t}^*}{NT_{2,t}^*} \tag{7}$$

$$q_t^*[(T_{1,t}^*)^{\alpha(1-\gamma)-1}(NT_{1,t}^*)^{(1-\alpha)(1-\gamma)}=$$

$$\beta E_t[[(T_{1,t+1}^*)^{\alpha(1-\gamma)-1}(NT_{1,t+1}^*)^{(1-\alpha)(1-\gamma)}] \tag{8}$$

$$q_t^*[(T_{2,t}^*)^{\alpha(1-\gamma)-1}(NT_{2,t}^*)^{(1-\alpha)(1-\gamma)}=$$

$$\beta E_t[[(T_{2,t+1}^*)^{\alpha(1-\gamma)-1}(NT_{2,t+1}^*)^{(1-\alpha)(1-\gamma)}] \tag{9}$$

$$q_t^* p_{1,t}^*[(T_{1,t}^*)^{\alpha(1-\gamma)}(NT_{1,t}^*)^{(1-\alpha)(1-\gamma)-1}=$$

$$\beta E_t[[p_{1,t+1}^*(T_{1,t+1}^*)^{\alpha(1-\gamma)}(NT_{1,t+1}^*)^{(1-\alpha)(1-\gamma)-1}] \tag{10}$$

$$q_t^* p_{2,t}^*[(T_{2,t}^*)^{\alpha(1-\gamma)}(NT_{2,t}^*)^{(1-\alpha)(1-\gamma)-1}=$$

$$\beta E_t[[p_{2,t+1}^*(T_{2,t+1}^*)^{\alpha(1-\gamma)}(NT_{2,t+1}^*)^{(1-\alpha)(1-\gamma)-1}] \tag{11}$$

$$T_{1,t}^*+p_{1,t}^*NT_{1,t}^*+q_t^*b_{1,t+1}^*=\bar{T}_{1,t}+p_{1,t}^*\bar{NT}_{1,t}+\bar{b}_{1,t} \tag{12}$$

$$T_{2,t}^*+p_{2,t}^*NT_{2,t}^*+q_t^*b_{2,t+1}^*=\bar{T}_{2,t}+p_{2,t}^*\bar{NT}_{2,t}+\bar{b}_{2,t} \tag{13}$$

$$T_{1,t}^*+T_{2,t}^*=\bar{T}_{1,t}+\bar{T}_{2,t} \tag{14}$$

$$NT_{1,t}^*=\bar{NT}_{1,t} \tag{15}$$

$$NT^*_{2,t}=\bar{NT}_{2,t} \tag{16}$$

$$b^*_{1,t+1}+b^*_{2,t+1}=0 \tag{17}$$

$$\bar{b}_{1,0}=\bar{b}_{2,0}=0 \tag{18}$$

These Euler equations have the standard interpretation. Equations (6) and (7) express the relative price of nontradables in terms of tradables as the ratio of their marginal utilities which, in this case, equals the consumption ratio, adjusted for ratio of the weights of tradables and nontradables in the utility function. 1/ With perfect international capital mobility, the real interest rate in terms of tradables (r) is equal across countries. Equations (8) and (9) express the price of the discount bond which equals 1/(1+r) as a function of the expected change in the marginal utility of the tradable good in both countries. Equations (10) and (11) state the same intertemporal relationship in terms of the nontradable good, hence the additional price of nontradables in terms of tradables. The other equations represent the budget constraints for both agents and the resource constraints. The last constraint imposes that both agents start with zero wealth in the first period. 2/

The real exchange rate, in terms of the total consumption basket, can be defined as follows: 3/

$$REER_t=\left(\frac{p^*_{1,t}}{p^*_{2,t}}\right)^{(1-\alpha)} \tag{19}$$

This definition, which treats the real exchange rate as the relative price of nontradables in both countries, is used in the empirical work.

1/ Given the specification of the utility function, this condition also ensures that spending on nontradables is a constant fraction of total spending in every period.

2/ Since there are no outside assets in the model, the terms wealth and net foreign assets can be used interchangeably.

3/ Given that the model is formulated in terms of tradables, the price of tradables always equals one and drops out of this equation.

Solving this set of equations for a representative agent is straightforward. Every agent receives half of each endowment in every period and the stock of assets for each agent always equals zero. Replacing all starred variables with half of the endowments allows us to solve for the real exchange rate and the interest rate. 1/ In this case a specification of the law of motion for the endowment streams is sufficient to characterize the prices.

Unfortunately, introducing heterogeneity in this model adds a layer of complexity to its solution. To see this, it is instructive to replace NT^{*}_{1} in equation (12) with the endowment of the nontradable in country 1 (making use of equation (15)). In that case, equation (10) simplifies to:

$$T^{*}_{1,t}-\bar{T}_{1,t}=b^{*}_{1,t}-q^{*}_{t}b^{*}_{1,t+1} \tag{20}$$

This equation expresses the trade balance for the resident of country 1. 2/ He invests the difference of his consumption of the tradable good and his endowment in period t in the claim on next period's endowment of the tradable good. It is clear that b_t can be replaced with the past values of this differential and the initial stock of wealth. Hence, the distribution of wealth across agents is a factor in period *t's* consumption and savings decision which raises two further issues, one of a conceptual the other of a computational nature.

On a conceptual level, Giavazzi and Wyplosz (1984) showed that, in its current format, the model generates an infinite number of steady states for exchange rates and net foreign asset positions. As pointed out by Krugman (1984), this property hinges upon the assumptions of an infinite horizon, time-separable utility functions with identical rates of time preference across countries and perfect asset substitutability. In two seminal papers, Clarida (1987, 1990), analyzes the behavior of the current account and net foreign assets in a model without aggregate uncertainty where consumers face liquidity constraints. He shows that a unique stationary distribution of net foreign assets exists across countries and that there is a constant fraction of consumers who, in equilibrium, face a binding liquidity constraint. 3/ This literature suggests three approaches to resolving this indeterminacy empirically. First, the rate of time preference can be endogenized as suggested by Obstfeld (1982). Second, discontinuous constraints can be imposed on the stock of net foreign assets or on the size of the trade balance deficit. Third, the assumption of perfect asset

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1/ Note that this, per definition, implies that the trade balance and the stock of net foreign assets are equal to zero in every period.

2/ By Walras Law, this equals the trade balance of the resident in the second country.

3/ In addition, he analyzes the effects of different rates of time preference and taxation across countries.

substitutability can be relaxed by introducing a risk premium that increases in the size of net external lending. In the empirical section, we pursue this third option and incorporate a risk premium in the budget constraints (expressed, in different formats, in equations (2), (12), (13) and (20)) as follows:

$$T_{i,t}+p_{i,t}NT_{i,t}+(q_t-rp_t)b_{i,t+1}\leq\bar{T}_{i,t}+p_{i,t}\bar{NT}_{i,t}+b_{i,t} \qquad (21)$$

where $rp_{i,t} > 0$ when $b_{i,t} < 0$ and vice-versa. This risk premium is rising in the stock of net foreign liabilities and limits the distribution of net foreign assets over time. In this model, we define rp as the absolute value of $b_{i,t+1}{}^{2/3}$ multiplied by .01.

On the computational side, the distribution of wealth becomes a state variable which varies over time and cannot be characterized in closed-form solution, except under very specific assumptions. The next subsection is devoted to explaining the empirical strategy on how to cope with this problem.

3. Solution method

There are several techniques available to solve this type of optimization problems. 1/ The purpose of this section is to provide a brief overview of one of those methods--the parametrized expectation method--used in the empirical section. We refer the reader to Danthine and Donaldson (1995), den Haan (1994), and den Haan and Marcet (1990), for a more technical exposition. Equations (8) and (9) can be written in a more general form as follows:

$$q_t^*U_T(T_{i,t}^*,NT_{i,t}^*)=\beta E_t[U_T(T_{i,t+1}^*,NT_{i,t+1}^*)] \qquad (22)$$

The key problem is that the form of the conditional expectation is unknown, unlike in the representative agent's case. The method of parametrized expectations expresses this expectational term as a linear function of the state variables. In this case, the state variables comprise the endowment shock for tradables and nontradables, the wealth of the individual in country i and the distribution of wealth over all agents. 2/ The point of this approach is to approximate this conditional expectation as well as possible by this function. Marcet and Marshall (1990), show that

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1/ See Taylor and Uhlig (1992), for an overview of the alternative solution techniques in a closed-economy context.

2/ Note that in the case with two agents, one agent's wealth describes the whole distribution given the assumption that there are no outside assets.

any polynomial (or its log) can approximate this conditional expectation arbitrarily well.

Formally, define this function Z as:

$$Z(T^*_{i,t},T^*_{-i,t},NT^*_{i,t},NT^*_{-i,t},\Phi^*_{i,t},\Phi^*_{-i,t})=$$

$$\delta_0+\delta_1 T^*_{i,t}+\delta_2 NT^*_{i,t}+\delta_3 T^*_{-i,t}+\delta_4 NT^*_{-i,t}+\delta_5\Phi^*_{i,t}+\delta_6\Phi^*_{-i,t} \tag{23}$$

where $\Phi_{i,t}$ measures the wealth of individual i in period t and $\Phi_{-i,t}$ is the distribution of wealth of all agents except individual i at time t (to be defined later).

At this point, the vector δ has to be chosen such that it approximates the right-hand side of equation (23) as well as possible. This can be done by the following 6-step iterative procedure:

1. Approximate the law of motion for the exogenous state variables, endowments of tradables and nontradables, for both countries. This can be done through a vector-autoregression.

2. Generate a sample of size T (e.g. T=200) from this law of motion.

3. Plug in the values for period 1 from this sample in equation (23), and guess an initial value for the vector δ (e.g. δ = 1). Since each individual has zero wealth in period 0, the first period wealth distribution is just the realization of the endowments for tradables and nontradables. This allows for the calculation of Zeta in the second period.

4. With a guess for period zero consumption of tradables and nontradables, q_0 can be calculated. Inserting the value for q in equation (20) yields the asset position of individual 1 in period 1. Steps 1 through 4 can now be performed for the second agent. In order for these values for consumption and prices to be an equilibrium, however, the world resource constraints have to be satisfied. Specifically, the bond holdings for period 1 have to be in zero net supply. If this is not the case, plug in a different value for period zero consumption and start the process anew until this constraint is satisfied.

5. Once this iteration is completed, the whole process can be moved forward one period to calculate q_1 and consumption in period 1, given the values for the endowment generated in period 1. We can follow this procedure until we have calculated a value for Z, q and Φ for all observations.

6. These values can now be used to re-estimate equation (23). The whole procedure can then be started again with step 1 with the estimated

values for delta. The whole sequence stops when a convergence criterion is satisfied.

The empirical results from this procedure are now presented in the next section.

IV. Simulation Results

Charts A.1 through A.13 in the appendix report per capita output for tradables and nontradables (in nominal and real terms), price indices for these series and the price of nontradables in terms of tradables. 1/ Charts A.10 and A.11 present this evidence for the U.S.-based simulations. Both tradables and nontradables output exhibits strong growth throughout the sample period. In both the United States and the rest-of-the-world, nontradables prices rose more rapidly than tradables prices. However, this evolution in the rest of the world was more pronounced than in the United States leading to a steady decline of the U.S. dollar in real effective terms. 2/ Charts A.7 and A.12 report similar data for the Japan-based simulations. The evolution of tradables versus nontradables prices is reflected in a very steep appreciation of the Japanese yen in real effective terms. The data used for the German-based simulations, as reported in charts A.4 and A.13, are similar to those in the U.S.-based simulation. In the 1980s, however, the price of German nontradables rises apace with the price of tradables, leading to a depreciation of the real effective value of the DM from the 1980s on. As chart 4 indicated and has been discussed in section II, this measure of the real exchange rate (REER in Chart 4) is similar to the real exchange rate measure based upon relative movements in consumer and producer price indices (REER3) but is quite different from the real effective exchange rate as measured in International Financial Statistics (REER2) and a terms of trade measure (REER4). See Feldman (1994), for a detailed discussion.

The time series characteristics of the real output series for tradables and nontradables underlying our simulations are reported in Tables 1 through 3. These tables report the results of a first-order VAR on the growth rate of the per capita output series. Growth rates were taken to render the equations stationary--a necessary condition for the Euler equations in section III.2 to hold. Table 1 presents the coefficients of this first order VAR for the U.S.-based simulation. Several features stand out. First, the growth rate of each of the four series is positively related with the growth rate of U.S. tradables lagged one period. A positive shock to growth in U.S. nontradables, however, has a negative impact on next period growth of in tradables and nontradables at home and abroad. Innovations in

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1/ Appendix A provides a detailed description of the data construction.
2/ As has been pointed out earlier, the real effective exchange rate is defined as in equation (19), e.g. it is the ratio of the two price baskets.

Table 1. United States: First-order Vector Autoregressiion for the Exogenous Variables

Estimated Coefficients				
Constant	U.S. Tradables	U.S. Nontradables	ROW Tradables	ROW Nontradables
1.22 (0.51)	0.30 (0.30)	-0.08 (0.20)	0.08 (0.54)	-0.52 (0.71)
2.12 (1.31)	0.76 (0.77)	-0.71 (0.52)	-0.38 (1.39)	-0.79 (1.82)
0.75 (0.37)	0.15 (0.22)	0.00 (0.15)	-0.37 (0.40)	0.46 (0.52)
0.92 (0.25)	0.14 (0.15)	0.04 (0.10)	0.13 (0.27)	-0.23 (0.35)

Variance-Covariance Matrix

0.0011	0.0009	0.0003	0.0002
0.0009	0.0074	0.0001	0.0007
0.0003	0.0001	0.0006	0.0000
0.0002	0.0007	0.0000	0.0003

Note: Each row in the first panel gives the coefficients for an equation. The first equation has the growth rate of the home country's output of tradables as its dependent variable. The second, third and fourth equations have the growth rate of domestic nontradables and rest-of-the-world tradables and nontradables as dependent variables respectively. The numbers between brackets are the standard errors. The data are annual for 1970-92. The ROW includes Belgium, Canada, Germany, Italy, Japan, Sweden and the United Kingdom.

Table 2. Japan: First-order Vector Autoregression for the Exogenous Variables

		Estimated Coefficients		
Constant	U.S. Tradables	U.S. Nontradables	ROW Tradables	ROW Nontradables
-0.06	-0.05	0.91	-0.24	0.44
(0.66)	(0.44)	(0.48)	(0.42)	(0.62)
1.04	-0.43	0.22	0.32	-0.15
(0.39)	(0.26)	(0.29)	(0.25)	(0.37)
1.27	-0.73	0.60	0.56	-0.70
(0.59)	(0.39)	(0.43)	(0.38)	(0.55)
0.99	-0.45	0.42	0.42	-0.37
(0.39)	(0.26)	(0.29)	(0.25)	(0.37)

Variance-Covariance Matrix

0.0011	0.0001	0.0005	-0.0001
0.0001	0.0004	0.0001	-0.0000
0.0005	0.0001	0.0009	0.0003
-0.0001	-0.0000	0.0003	0.0004

Note: Each row in the first panel gives the coefficients for an equation. The first equation has the growth rate of the home country's output of tradables as its dependent variable. The second, third and fourth equations have the growth rate of domestic nontradables and rest-of-the-world tradables and nontradables as dependent variables respectively. The numbers between brackets are the standard errors. The data are annual for 1970-92. The ROW includes Belgium, Canada, Germany, Italy, Japan, Sweden and the United Kingdom.

Table 3. Germany: First-order Vector Autoregression for the Exogenous Variables

		Estimated Coefficients		
Constant	U.S. Tradables	U.S. Nontradables	ROW Tradables	ROW Nontradables
0.55 (0.83)	-0.54 (0.44)	0.80 (1.06)	0.48 (0.43)	-0.27 (0.46)
0.58 (0.20)	-0.02 (0.11)	0.49 (0.26)	-0.10 (0.10)	0.05 (0.11)
-0.19 (0.84)	-1.00 (0.45)	1.73 (1.07)	0.52 (0.43)	-0.07 (0.46)
0.86 (0.43)	-0.31 (0.23)	-0.12 (0.55)	0.42 (0.22)	0.14 (0.24)

Variance-Covariance Matrix

0.0009	0.0001	0.0007	-0.0002
0.0001	0.0001	0.0001	-0.0000
0.0007	0.0001	0.0009	0.0001
-0.0002	-0.0000	0.0001	0.0002

Note: Each row in the first panel gives the coefficients for an equation. The first equation has the growth rate of the home country's output of tradables as its dependent variable. The second, third and fourth equations have the growth rate of domestic nontradables and rest-of-the-world tradables and nontradables as dependent variables respectively. The numbers between brackets are the standard errors. The data are annual for 1970-92. The ROW includes Belgium, Canada, Germany, Italy, Japan, Sweden and the United Kingdom.

the ROW growth of tradables and nontradables have the opposite effect. 1/

Tables 2 and 3 report the coefficients for the VARs used in the Japan and German-based simulations. Both lagged Japanese and German tradables have a negative effect on tradables and nontradables growth at home and abroad. For nontradables, the opposite holds except German nontradables which also have a negative impact on foreign nontradables. The coefficients on ROW output of tradables and nontradables indicate mixed effects on those variables at home and abroad.

Tables 4 through 6 report the statistics for the actual and simulated data. Each panel reports the mean, standard deviation, maximum, minimum and one-period autocorrelation for the output of tradables and nontradables, total consumption of tradables and nontradables, the real interest rate, and the price of nontradables in terms of tradables for the reference country and the rest of the world. In addition, the same statistics are reported for the trade balance as a percentage of GNP, the real effective exchange rate (as defined in equation (19)) and the net foreign asset position as a percentage of GNP for the reference country. Consumption and output series have been normalized to average one. Panel A in each graph report the observed values for those variables during 1970-92, sampled annually. All series, except for the interest rate series, have been detrended using the Hodrick-Prescott filter.

Panel B in graphs 4-6 reports the corresponding statistics for the simulated series. All simulation results are based upon a discount factor β of .95, an equal weight of tradables and nontradables in the utility function (α = .5) and an elasticity of intertemporal substitution γ equal to .33. 2/

1. Simulation results with the United States as reference country

The output of tradables, detrended and normalized to average unity, has a standard deviation of 0.04 with extreme values of 5.4 percent above and 7.2 percent below the average and an autocorrelation of 54 percent. Consumption is slightly more volatile and exhibits a higher degree of serial correlation. The actual short-term real interest rate averaged 1.29 percent during 1970-92 (see Table 4, Panel A) with a standard deviation of 2.14. Its extreme values during this sample period were 6.94 percent and -4.2 percent with a first-order autocorrelation of 76 percent. The fifth column of panel A indicates that the price of the detrended nontradables

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1/ As the standard errors--reported as the numbers between brackets in the tables--indicate, some of the coefficients are quite imprecisely estimated and the point coefficients should be interpreted with caution.

2/ In order to ensure the existence of stationary decision rule to solve the model, all series for the output of tradables and nontradables were detrended using a Hodrick-Prescott filter. On the relative merits of different detrending procedures, see Canova and Dellas (1993), Asea and Mendoza (1995), Harvey and Jaeger (1993) and Baxter and King (1995).

Table 4. Simulation Results with United States as Home Country

Panel B: Moments for the Actual Series During 1970-92

	United States					Rest of the World					United States		
	$\bar{T}_1$	$\bar{NT}_1$	C_1	r_1	P_1	$\bar{T}_1$	$\bar{NT}_2$	C_2	r_2	P_2	TB_1	REER	NFA_1
Avg.	1.00	1.00	1.00	1.29	1.01	1.00	1.00	1.00	2.01	0.85	-1.06	1.09	3.29
Std.	0.03	0.03	0.04	3.09	0.02	0.02	0.02	0.04	3.54	0.01	0.66	0.01	2.15
Maximum	1.05	1.04	1.08	6.94	1.07	1.04	1.03	1.11	6.34	0.87	0.12	1.12	7.17
Minimum	0.93	0.95	0.95	-4.20	0.97	0.97	0.98	0.93	-6.02	0.84	-2.23	1.07	0.05
ρ	0.54	0.64	0.79	0.76	0.43	0.38	0.63	0.77	0.83	0.52	0.61	0.58	0.57

Panel B: Moments for the Simulated Series

	United States					Rest of the World					United States		
	$\bar{T}_1$	$\bar{NT}_1$	C_1	r_1	P_1	$\bar{T}_1$	$\bar{NT}_2$	C_2	r_2	P_2	TB_1	REER	NFA_1
Avg.	1.00	1.00	1.00	5.09	1.00	1.00	1.00	1.00	5.10	1.00	0.05	1.00	0.23
Std.	0.03	0.04	0.02	4.89	0.05	0.02	0.01	0.02	3.41	0.02	0.87	0.03	1.13
Maximum	1.07	1.17	1.06	20.74	1.22	1.04	1.04	1.06	14.68	1.05	2.50	1.11	3.28
Minimum	0.93	0.86	0.93	-14.26	0.83	0.95	0.97	0.95	-7.60	0.96	-2.96	0.90	-2.76
ρ	0.60	-0.16	0.42	-0.16	-0.25	0.25	0.42	0.42	0.29	0.19	-0.09	-0.24	0.72

Notes: Panel A reports the statistics for the actual detrended data. Avg. refers to the mean of the series, STD to its standard deviation, Max. (Min.) to the maximum (minimum) value of the series and ρ refers to the first-order autogressive correlation. $\bar{T}$, $\bar{NT}$, C_i, r, and P_i denote country i's output of tradables, nontradables output, total consumption, consumption-based interest rate and price of nontradables in terms of tradables respectively. i = 1 refers to the reference country and i = 2 refers to the rest of the world. TB_1 is the trade balance as a percentage of GDP of the reference country. REER is the real effective exchange rate as defined in the text. NFA is the net foreign asset position as a percentage of GDP for the home country. Panel B reports the same statistics for the simulated series. Output and consumption series are normalized to average unity.

Table 5. Simulation Results with Japan as Home Country

Panel B: Moments for the Actual Series During 1970-92

	Japan					Rest of the World					Japan		
	$\bar{T}_1$	$\bar{NT}_1$	C_1	r_1	P_1	$\bar{T}_2$	$\bar{NT}_2$	C_2	r_2	P_2	TB_1	REER	NFA_1
Avg.	1.00	1.00	1.00	1.76	0.86	1.00	1.00	1.00	1.62	0.95	1.44	0.94	5.27
Std.	0.02	0.02	0.03	4.42	0.01	0.03	0.02	0.04	3.13	0.01	1.07	0.01	1.39
Maximum	1.05	1.03	1.08	5.94	0.88	1.05	1.03	1.08	6.22	0.98	3.24	0.97	7.87
Minimum	0.95	0.97	0.94	-15.26	0.83	0.94	0.96	0.94	-3.73	0.93	-0.38	0.93	2.96
ρ	0.38	0.49	0.68	0.43	0.27	0.53	0.65	0.84	0.37	0.50	0.50	0.59	0.36

Panel B: Moments for the Simulated Series

	Japan					Rest of the World					Japan		
	$\bar{T}_1$	$\bar{NT}_1$	C_1	r_1	P_1	$\bar{T}_2$	$\bar{NT}_2$	C_2	r_2	P_2	TB_1	REER	NFA_1
Avg.	1.00	1.00	1.00	5.34	1.00	1.00	1.00	1.00	5.34	1.00	0.06	1.00	0.63
Std.	0.03	0.02	0.02	4.64	0.02	0.03	0.02	0.02	4.66	0.02	0.80	0.01	1.27
Maximum	1.07	1.06	1.05	18.53	1.05	1.07	1.04	1.06	17.34	1.09	2.13	1.03	4.96
Minimum	0.90	0.95	0.93	-5.87	0.94	0.91	0.96	0.93	-6.64	0.92	-3.36	0.97	-3.40
ρ	0.35	0.54	0.37	0.35	0.16	0.54	0.54	0.43	0.31	0.36	0.52	0.34	0.83

Notes: Panel A reports the statistics for the actual detrended data. Avg. refers to the mean of the series, STD to its standard deviation, Max. (Min.) to the maximum (minimum) value of the series and ρ refers to the first-order autogressive correlation. $\bar{T}$, $\bar{NT}$, C_i, r, and P_i denote country i's output of tradables, nontradables output, total consumption, consumption-based interest rate and price of nontradables in terms of tradables respectively. i = 1 refers to the reference country and i = 2 refers to the rest of the world. TB_1 is the trade balance as a percentage of GDP of the reference country. REER is the real effective exchange rate as defined in the text. NFA is the net foreign asset position as a percentage of GDP for the home country. Panel B reports the same statistics for the simulated series. Output and consumption series are normalized to average unity.

Table 6. Simulation Results with Germany as Home Country

Panel B: Moments for the Actual Series During 1970-92

	Germany					Rest of the World					Germany		
	$\bar{T}_1$	$\bar{NT}_1$	C_1	r_1	P_1	$\bar{T}_2$	$\bar{NT}_2$	C_2	r_2	P_2	TB_1	REER	NFA_1
Avg.	1.00	1.00	1.00	3.21	0.83	1.00	1.00	1.00	1.47	0.95	3.63	0.94	9.09
Std.	0.02	0.01	0.07	2.05	0.01	0.03	0.02	0.04	3.38	0.01	0.88	0.01	2.23
Maximum	1.05	1.02	1.21	6.16	0.86	1.05	1.03	1.08	6.09	0.97	5.60	0.96	13.88
Minimum	0.95	0.98	0.87	-0.88	0.81	0.95	0.96	0.95	-5.51	0.93	1.32	0.93	5.58
ρ	0.42	0.65	0.71	0.41	0.65	0.50	0.66	0.82	0.81	0.27	0.55	0.56	0.70

Panel B: Moments for the Simulated Series

	Germany					Rest of the World					Germany		
	$\bar{T}_1$	$\bar{NT}_1$	C_1	r_1	P_1	$\bar{T}_2$	$\bar{NT}_2$	C_2	r_2	P_2	TB_1	REER	NFA_1
Avg.	1.00	1.00	1.00	5.26	0.98	1.00	1.00	1.00	5.27	1.02	0.81	0.98	3.68
Std.	0.02	0.01	0.02	3.51	0.02	0.02	0.01	0.02	3.52	0.02	0.55	0.01	0.83
Maximum	1.05	1.01	1.06	15.02	1.04	1.07	1.03	1.04	15.11	1.08	2.10	1.02	5.44
Minimum	0.94	0.99	0.93	-1.96	0.92	0.92	0.97	0.93	-2.66	0.95	-0.77	0.96	1.47
ρ	0.41	0.67	0.50	0.44	0.47	0.48	0.61	0.38	0.43	0.31	0.71	0.58	0.87

Notes: Panel A reports the statistics for the actual detrended data. Avg. refers to the mean of the series, STD to its standard deviation, Max. (Min.) to the maximum (minimum) value of the series and ρ refers to the first-order autogressive correlation. $\bar{T}$, $\bar{NT}$, C_i, r, and P_i denote country i's output of tradables, nontradables output, total consumption, consumption-based interest rate and price of nontradables in terms of tradables respectively. i = 1 refers to the reference country and i = 2 refers to the rest of the world. TB_1 is the trade balance as a percentage of GDP of the reference country. REER is the real effective exchange rate as defined in the text. NFA is the net foreign asset position as a percentage of GDP for the home country. Panel B reports the same statistics for the simulated series. Output and consumption series are normalized to average unity.

Its extreme values during this sample period were 6.94 percent and -4.2 percent with a first-order autocorrelation of 76 percent. The fifth column of panel A indicates that the price of the detrended nontradables series is not very volatile with a coefficient of variation (the standard deviation divided by the mean) of 0.021 and moves quite persistently over time.

The actual data for the rest of the world, defined as Belgium, Canada, Germany, Italy, Japan, Sweden and the United Kingdom, exhibit very similar characteristics. The volatility of the actual tradables output is also lower (.021 compared to .034) and the detrended price of nontradables is equally stable. The average for the short-term real interest rate is 72 basis points higher with volatility and autoregressive characteristics very similar to the U.S. interest rate.

The detrended U.S. trade balance, exports minus imports of goods and nonfactor services as a percentage of GNP, showed an average deficit of -1.06 percent during 1970-92 with a standard deviation of .66. Never during the sample did the trade balance exceed a surplus of .12 percent. It also showed strong persistence over time with a first-order correlation of 61 percent. The detrended real exchange rate was very stable, resulting from the low volatility in the price of nontradables in the United States and abroad but showed stronger persistence than either of the nontradables price indices. The detrended net foreign asset position averages 3.29 percent of GNP, with maximum values of 7.17 and 0.05 percent.

Panel B in Table 4 reports the same statistics for the simulated series. The first two columns of this panel report the same statistics for the simulated output series generated by the bootstrapping procedure as explained in section III.3. It is reassuring to see that the moments for the simulated <u>exogenous</u> variables are quite similar to those for the actual <u>exogenous</u> variables since the dynamics in those variables will determine the dynamics of the endogenous variables. Except for the wider extreme values for U.S. nontradables output, there is a close correspondence between the time series properties of the actual and simulated series.

The simulated consumption series in the United States is less volatile than actual consumption (with a standard deviation of for simulated consumption of .020 versus .037 for actual consumption). Real interest rates, calculated with a CPI deflator, are much higher on average both in the United States and abroad. 1/ In addition, they are more volatile, which is reflected in the higher standard deviation and more dispersed extreme values. This finding is consistent with results in similar exercises for closed economies models that have documented extensively the inability of this class of models to generate a sufficiently low real interest rate. 2/

We observe a significantly larger volatility in the relative price of nontradables in the United States and abroad compared to the statistics for the actual series: a standard deviation of .052 for the simulated U.S. series and .017 for the simulated price of nontradables in the ROW, compared to observed values of .021 and .006 respectively. The higher volatility is also reflected in more dispersed extreme values. The simulated trade balance is .05 percent of GDP which is very close to zero. This is so because the driving force behind the contemporaneous deviations between production and consumption is a desire on behalf of the optimizing agent to smooth consumption. Given our assumption of equal growth in the production of tradables in the United States and abroad (in our case put to zero), consumption will, on average, equal production and the trade balance will, on average, equal zero. The trade balance is, however, much more volatile than either consumption: its coefficient of variation is .62 compared to .09 for consumption and production. Given the absence of a trend in the trade balance, it is not surprising that the maximum value obtained in the simulation is significantly larger than the biggest observed trade balance during our sample period. In addition, the trade balance exhibits a slight negative autocorrelation compared to the actual data in which there is a high degree of positive autocorrelation.

The exchange rate is significantly more volatile than the observed real exchange rate. The standard deviation for the simulated series is about

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1/ Note that despite the fact that the average interest rate is equal in the United States and the rest-of-the-world, this is not imposed in the model but an equilibrium outcome for this particular set of countries given our assumption of no growth in either the tradables or nontradables sector and an equal weight on tradables in both countries' utility function. If one were to simulate this model on two countries that have much different expenditure shares on tradables and nontradables, it is very possible to find different levels for the real interest rate in equilibrium since the composition of the CPI would be very different across countries. The theoretical structure implies that real interest rates, measured in terms of tradables, must be equal across countries given our assumption of capital mobility. However, since the price of nontradables differs across countries, using a CPI deflator to calculate a consumption-based real interest rate results in different real interest rates across countries. Although the volatility of interest rates in the United States and abroad is different, we obtain an equal average in the United States and abroad because of the normalization of outputs to one in both countries.

2/ See Mehra and Prescott (1985), in a closed-economy context and Bekaert (1994), for a similar finding in a two-country model.

twice the size the standard deviation of the actual series. This is not surprising given the volatility of the relative price of nontradables which are also about twice as volatile as the observed series. The results for the net foreign asset position are also worth noting. As a percentage of GNP, the average net foreign asset position is below the observed chart (0.23 percent versus 3.29 percent between 1970-92), with a lower volatility but a higher serial autocorrelation. 1/

A clear picture emerges from this exercise. In contrast to observed consumption patterns, agents in this model share consumption risks to a larger degree than implied by the actual 1970-92 series. In order to insure against these idiosyncratic endowment shocks in tradables output, consumers engage in active trading to offset this idiosyncratic income risk which leads to a significantly more volatile trade balance. In order to induce countries to share risks, prices of nontradables act as an adjustment mechanism and vary more pronounced than in the observed series. 2/ These swings in the relative price of nontradables are reflected directly in a higher volatility of the real exchange rate since it is directly defined as the relative price of nontradables. 3/ From this perspective, the findings of a volatility in the trade balance and exchange rates that is larger than the volatility observed in 1970-92 are flip sides of the same coin.

2. Simulation results with Japan as reference country

The results for the Japan-based simulation, reported in table 5, reinforce the results with the United States as the reference country. Compared to the United States, observed real short-term interest rates have been slightly higher, 1.76 versus 1.29 percent, but also more volatile. Correspondingly, the average interest rate in the rest of the world during 1970-92 was lower than in the U.S.-based model since the United States is now included in this group. The statistics on the observed detrended relative prices, in Japan and abroad, are again quite similar to the U.S.-

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1/ These results for the net foreign asset position should be interpreted with caution since they are very sensitive to the specific functional form for the liquidity constraint. As was noted in section III.3, some type of liquidity constraint is necessary to prevent interest dynamics from taking over trade balance dynamics which leads to an explosive path for net foreign assets. Although different specifications for the liquidity constraints lead to very different simulated paths for net foreign assets, the results for the other endogenous variables remain very similar.

2/ Given the specific functional form for the utility function, the price of nontradables in terms of tradables is given by the ratio of consumption of tradables over the consumption of nontradables adjusted by their relative weights in the utility function--see equations (6) and (7).

3/ A look at chart 4 reveals that the "excess volatility" of the simulated exchange rate compared to the actual exchange rate depends on our choice of the benchmark exchange rate which is significantly less volatile than the some of the other exchange rate measures depicted in chart 4.

based case with the volatility of relative price of nontradables in the United States slightly higher than the Japanese prices. Production of tradables in Japan exhibits less autocorrelation than in the United States but exhibits similar behavior otherwise. The Japanese trade balance has, not surprisingly, averaged well over 1 percent during 1970-92 with swings between 3.24 and -0.38 percent. The detrended real exchange rate is again remarkably stable with a standard deviation of .009.

The simulation results for consumption and output are very similar to the U.S.-based results and the simulation for the Japanese external variables closely match the observed series. Simulated interest rates reach an average well above the observed average in Japan and abroad and are again too volatile. The relative price of nontradables exhibits a volatility of about twice the size of the actual volatility and simulated tradables consumption is slightly smoother than production. The trade balance is again very close to equilibrium on average and more volatile than either consumption or production. In this case, the real exchange rate volatility is very close to the its observed volatility, .013 for the simulated series versus .009 for the actual series. The net foreign asset position is close to zero (.63 percent of GNP) with maximum values of 4.96 and -3.40 percent. 1/

3. Simulation results with Germany as reference country

Simulated real interest rates in Germany and abroad are again significantly more volatile than actual rates in addition to being too high compared to the observed rates. Stable relative prices of nontradables lead to a very stable real effective exchange rate. Optimal consumption smoothing implies a volatility in the relative price of nontradables in Germany and the rest-of-the-world that is about 1.5 and twice the observed volatility for the reference country Germany and the rest-of-the-world respectively. In this simulation with Germany as the reference country, the real exchange rate volatility implied by optimizing consumption smoothing in the model is very close to actual data, 0.01 compared to .009 implying a strong positive correlation between the relative price of nontradables in both countries. The results for the trade balance and the net foreign asset position are similar to the results reported for the United States and Japan.

V. Conclusion

This paper addresses the role of exchange rate as an adjustment mechanism in a world with integrated capital markets where consumers smooth away idiosyncratic shocks to their income. It adapts solution techniques from the closed-economy growth model literature to an international context

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1/ The caveat expressed on the sensitivity of the results for the net foreign assets position in the discussion of the U.S.-based simulations applies here.

in which countries experience different shocks to their production of tradables and nontradables.

Simulation results for the United States, Japan and Germany for 1970-92 suggest that the degree of real exchange rate volatility arising from this consumption-smoothing behavior is larger than or, in the case of Germany, very close to the observed volatility in detrended multilateral real exchange rates. This finding is driven by the role that the relative price of nontradables plays as an adjustment mechanism to smooth income shocks across countries. In order to induce a country that experiences a positive endowment shock (relative to the other country) to run a trade balance surplus, the relative price of nontradables in the exporting country needs to fall relative to the price of nontradables in the importing country. Since the real exchange rate is defined as the ratio of both relative prices, adjusted for the share of nontradables in the consumption basket, this implies a depreciation of the exporting country's real exchange rate. The path of the exchange rate consistent with the trade flows that are necessary for consumers to smooth consumption is more volatile than the benchmark multilateral real exchange rates observed during 1970-92 for the United States, Japan and Germany.

Data Sources 1/

This appendix provides the sources for the data used in the paper. The series for tradables are constructed according to the methodology developed by in Stockman and Tesar (1995). Graphs A.1 through A.13 plot the output and price series for the individual countries.

Following Stockman and Tesar (1995), the output of tradable goods is defined as the sum of the following sectoral output levels: 2/

Agriculture, hunting, forestry and fishing
Mining
Manufacturing
Wholesale and retail trade, restaurants and hotels
Transport, storage and communication.

The output of nontradable goods is the sum of:
Electricity, gas and water
Construction
Finance, Insurance, real estate and business services
Community, social and personal services
Producers of government services.

These data are extracted in nominal and real terms for the following countries, with the sample period given in brackets:

Australia	(1974-92)
Belgium	(1960-92)
Canada	(1960-92)
France	(1977-92)
Germany	(1960-92)
Italy	(1970-92)
Japan	(1960-92)
Sweden	(1970-92)
United Kingdom	(1970-92)
United States	(1960-92)

These data are taken from table "GDP by Kind of Activity" in the OECD National Accounts. The data for the United States in this database are only available until 1987 and were updated using the National Income and Product Accounts in the Survey of Current Business. Since the series for the United Kingdom are only available in nominal terms, we use the price of services and non-durable goods as a proxies for the price index of tradables and nontradables and use those indices to construct the real series. All data are converted in U.S. dollars using the PPP exchange rates. The exchange rate series are obtained from the OECD Economic Outlook.

1/ The full data set is available from the author upon request.
2/ See Stockman and Tesar (1995), for an elaboration on the construction of the tradables and nontradables output series.

The multilateral real exchange rate and trade balance data in Charts 1 to 3 are obtained from International Financial Statistics. The source for the net foreign asset positions is Masson, Kremers and Horne (1993). The series are updated for 1991-92 using the IMF Balance of Payments Statistics.

CHART A1.

AUSTRALIA

PRODUCTION AND PRICES FOR TRADABLES AND NONTRADABLES

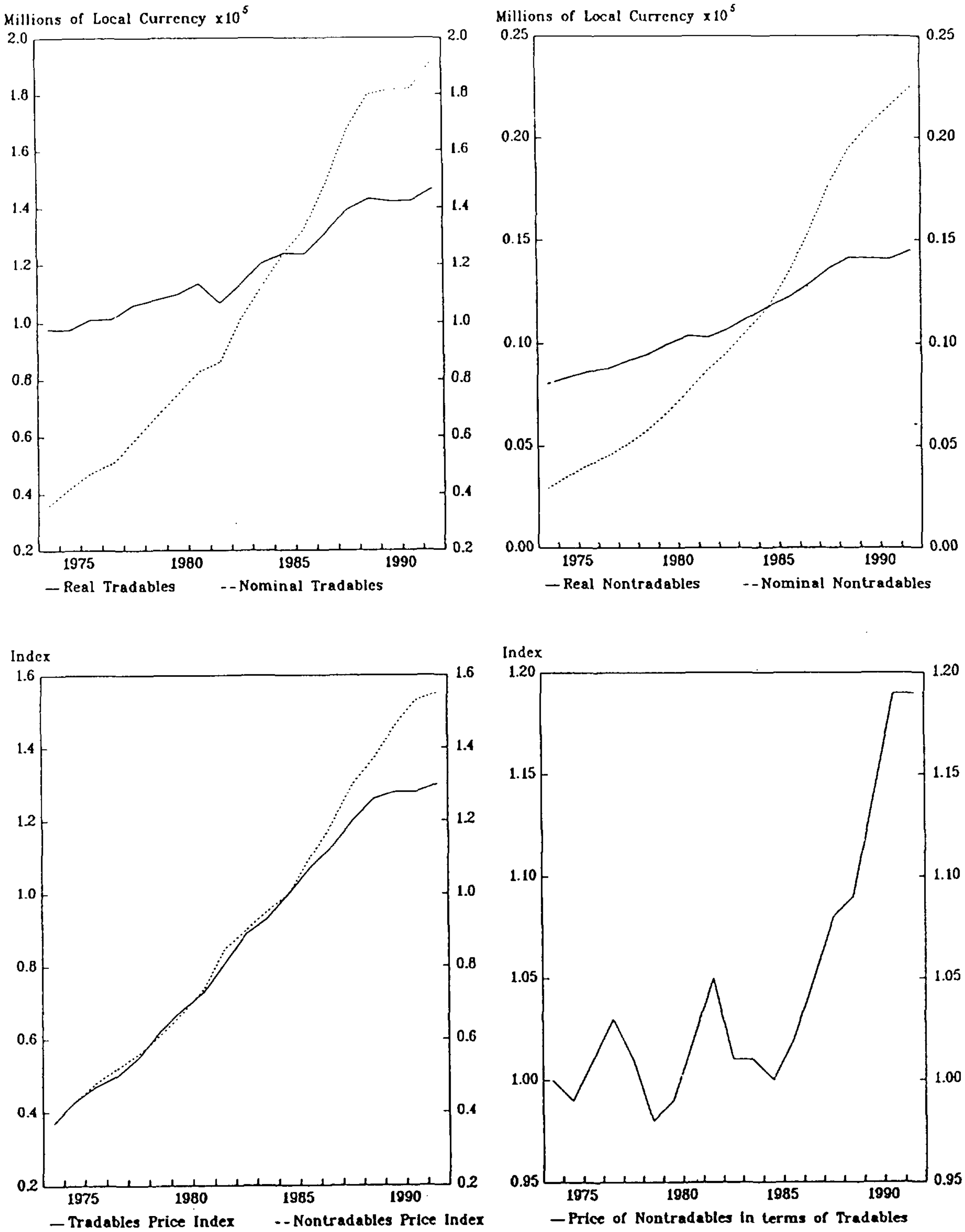


CHART A2.

BELGIUM

PRODUCTION AND PRICES FOR TRADABLES AND NONTRADABLES

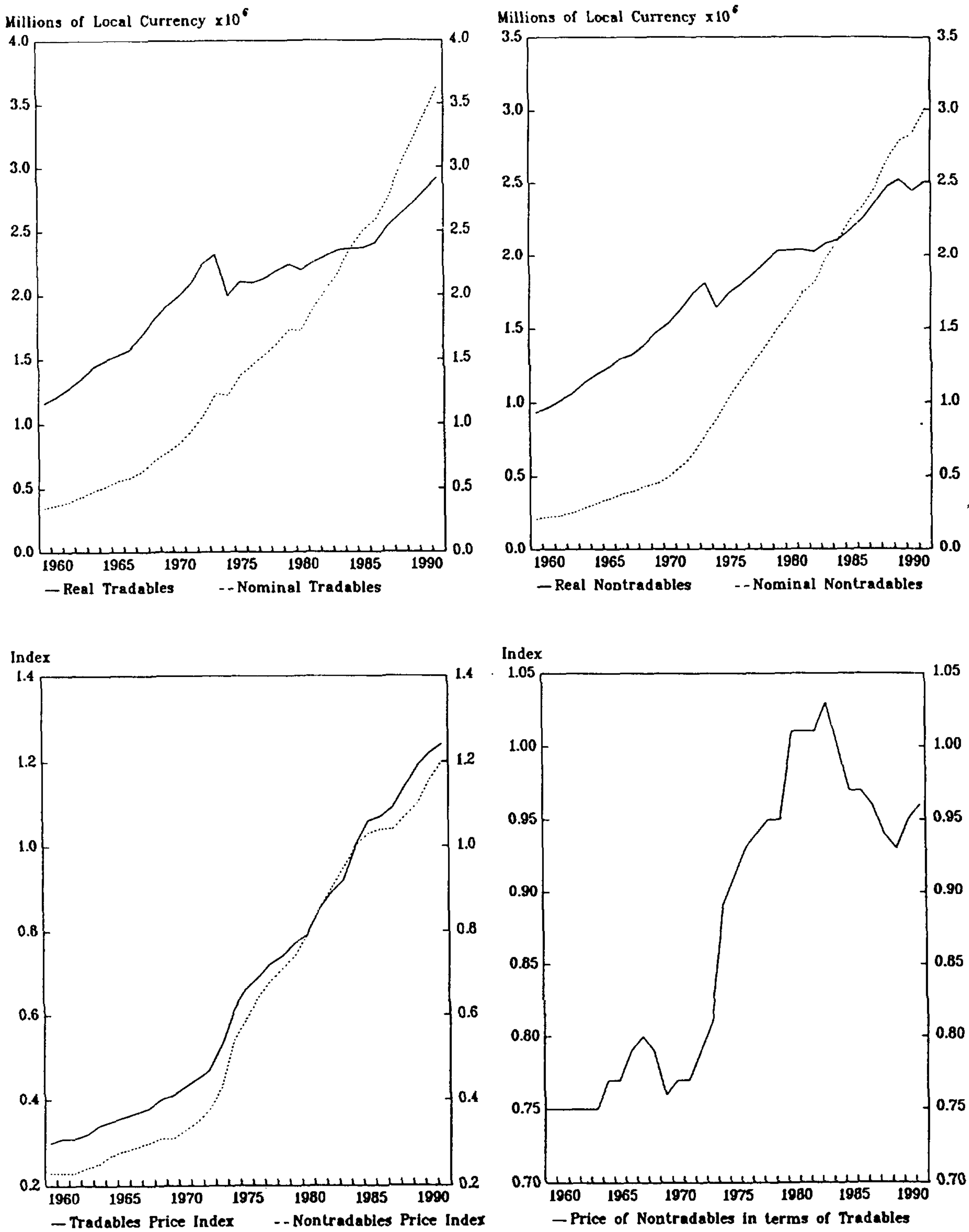


CHART A3.

CANADA

PRODUCTION AND PRICES FOR TRADABLES AND NONTRADABLES

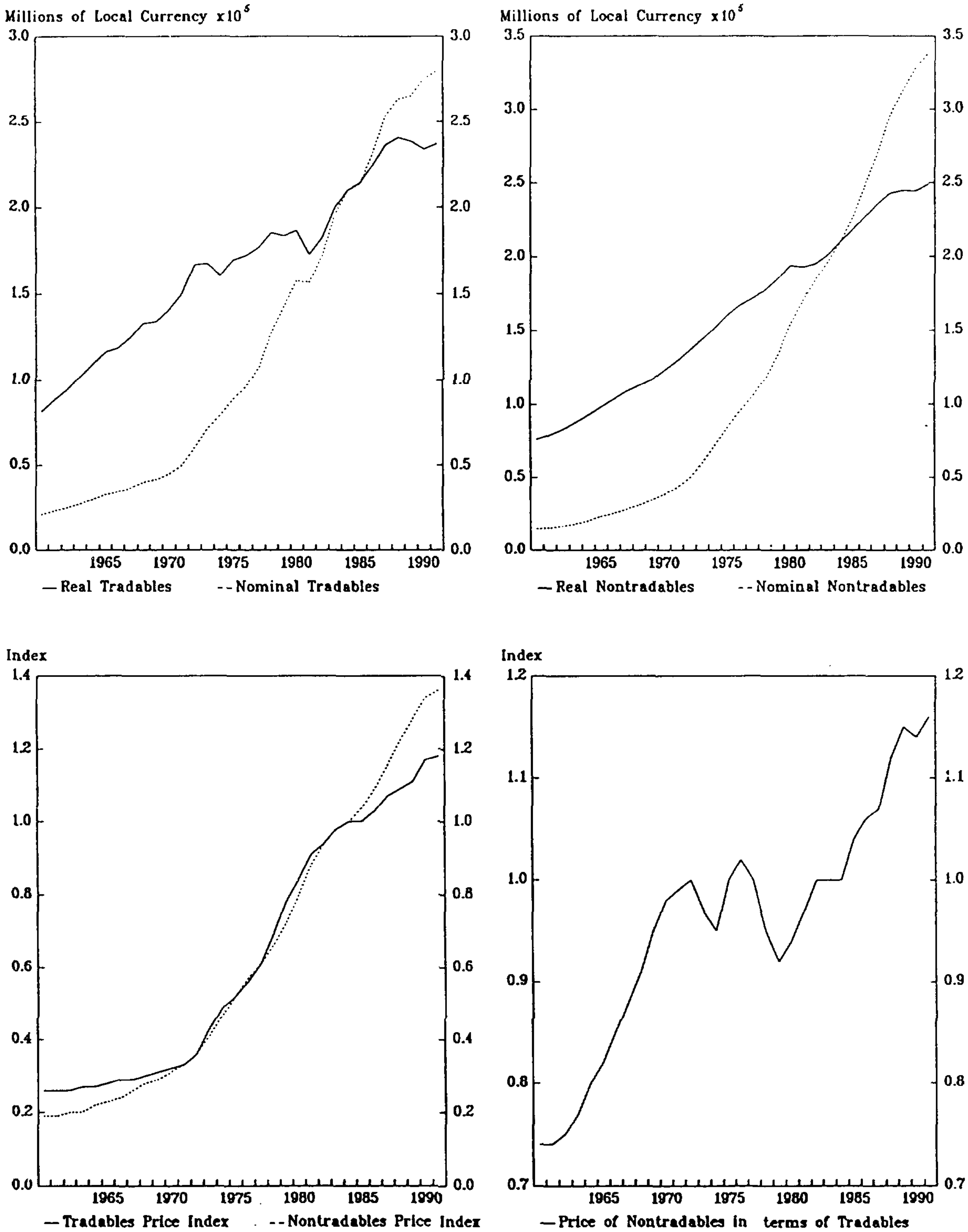
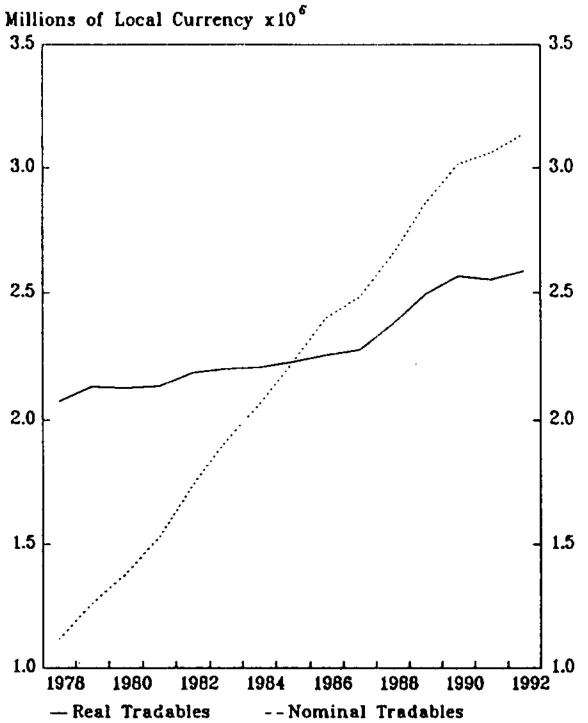
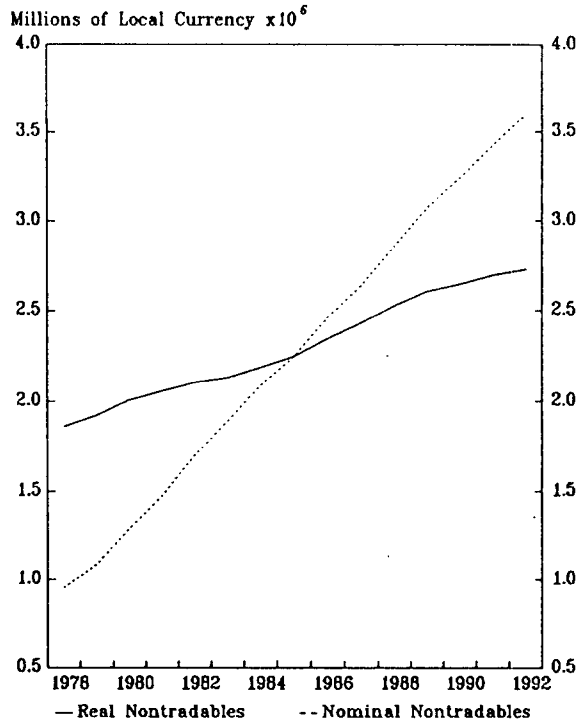


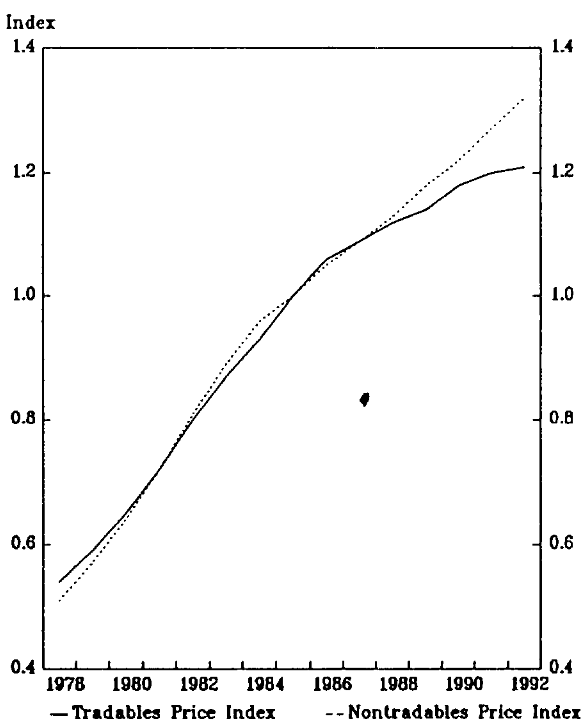
CHART A4.

FRANCE

PRODUCTION AND PRICES FOR TRADABLES AND NONTRADABLES







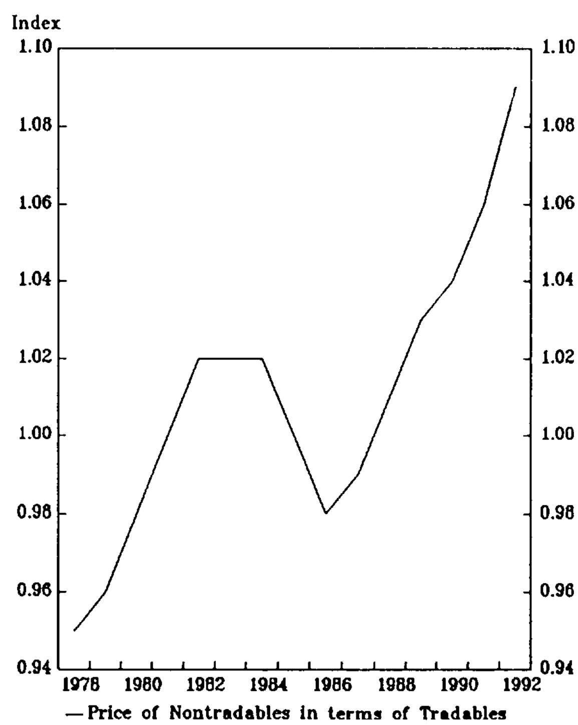


CHART A5.

GERMANY

PRODUCTION AND PRICES FOR TRADABLES AND NONTRADABLES

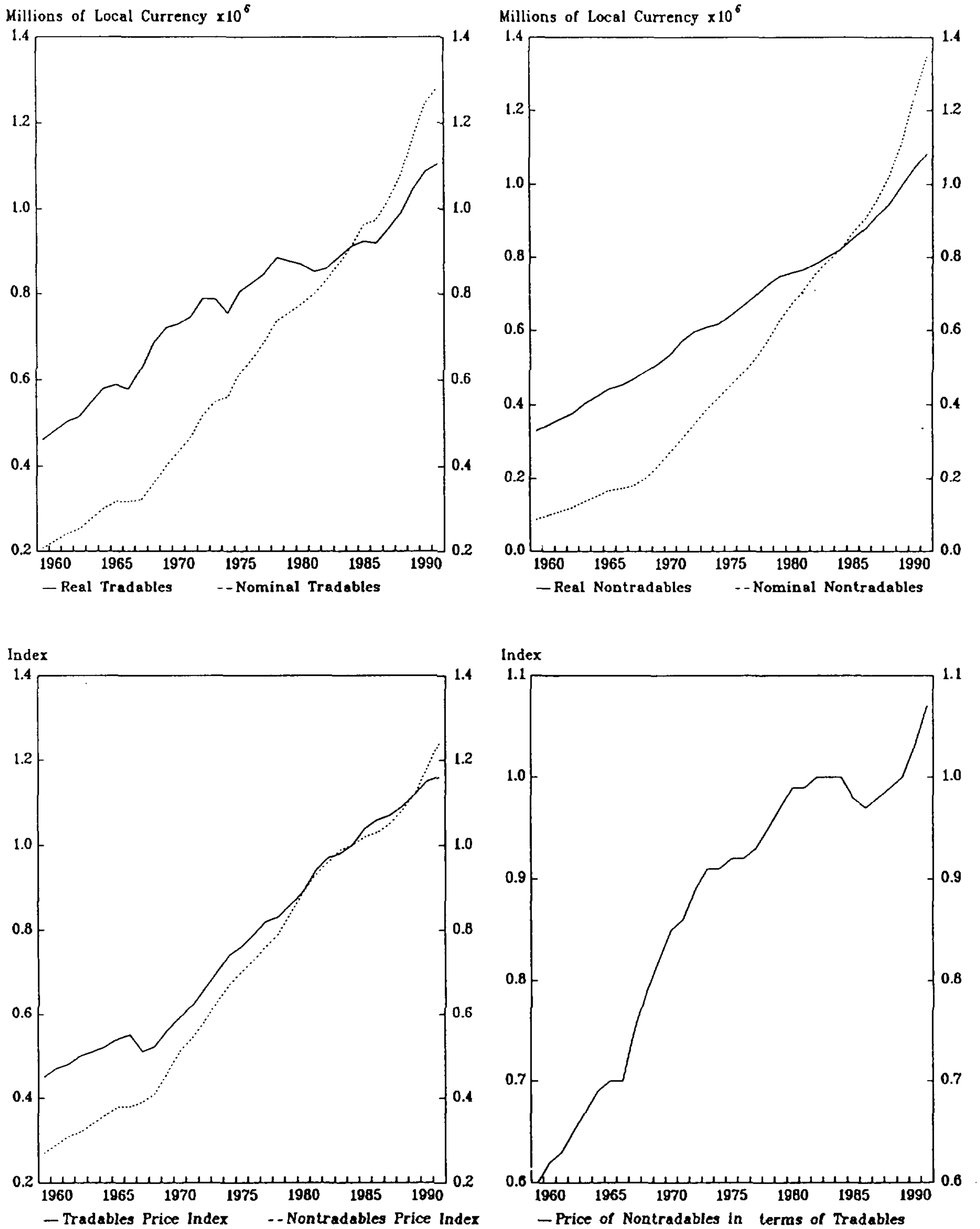
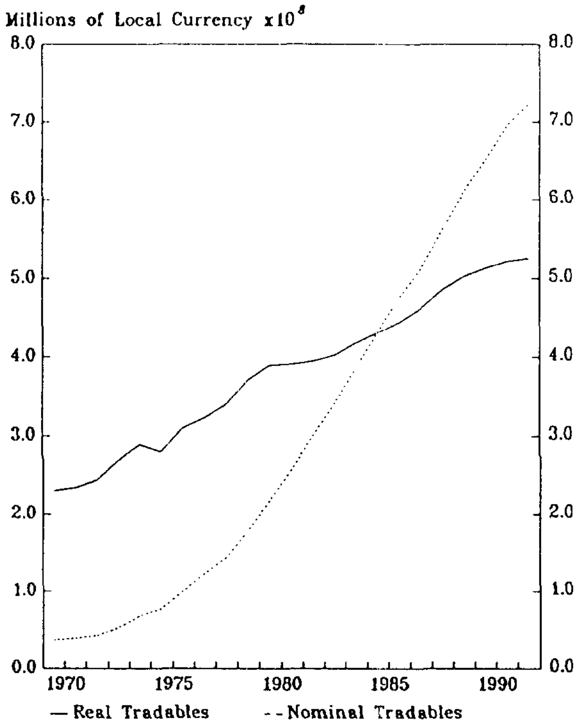
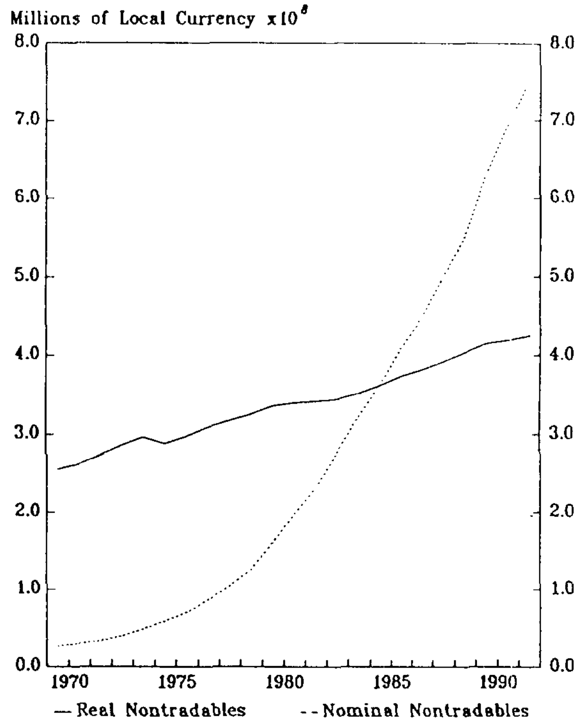


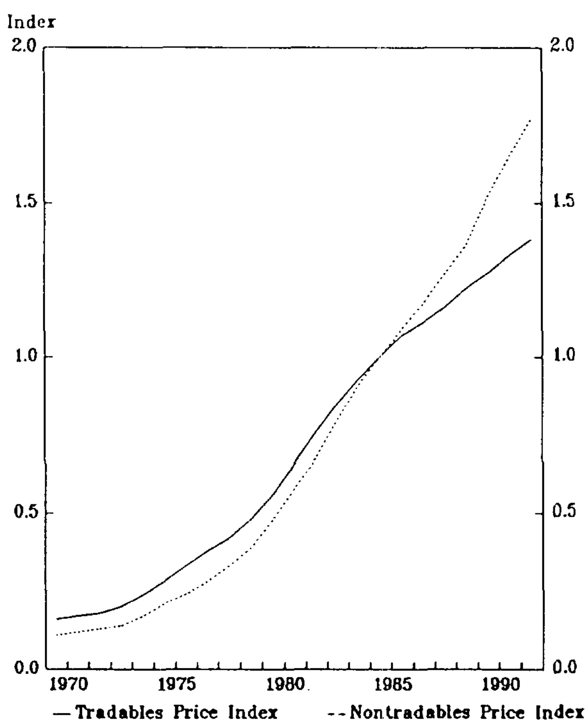
CHART A6.

ITALY

PRODUCTION AND PRICES FOR TRADABLES AND NONTRADABLES







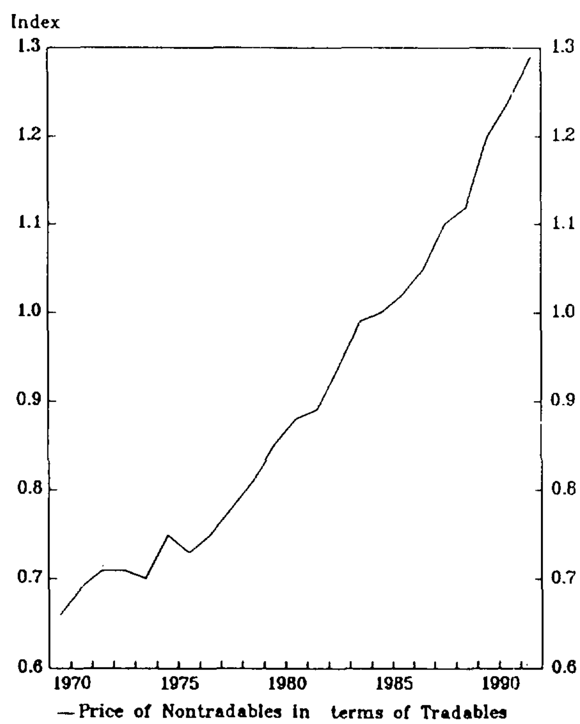


CHART A7.

JAPAN

PRODUCTION AND PRICES FOR TRADABLES AND NONTRADABLES

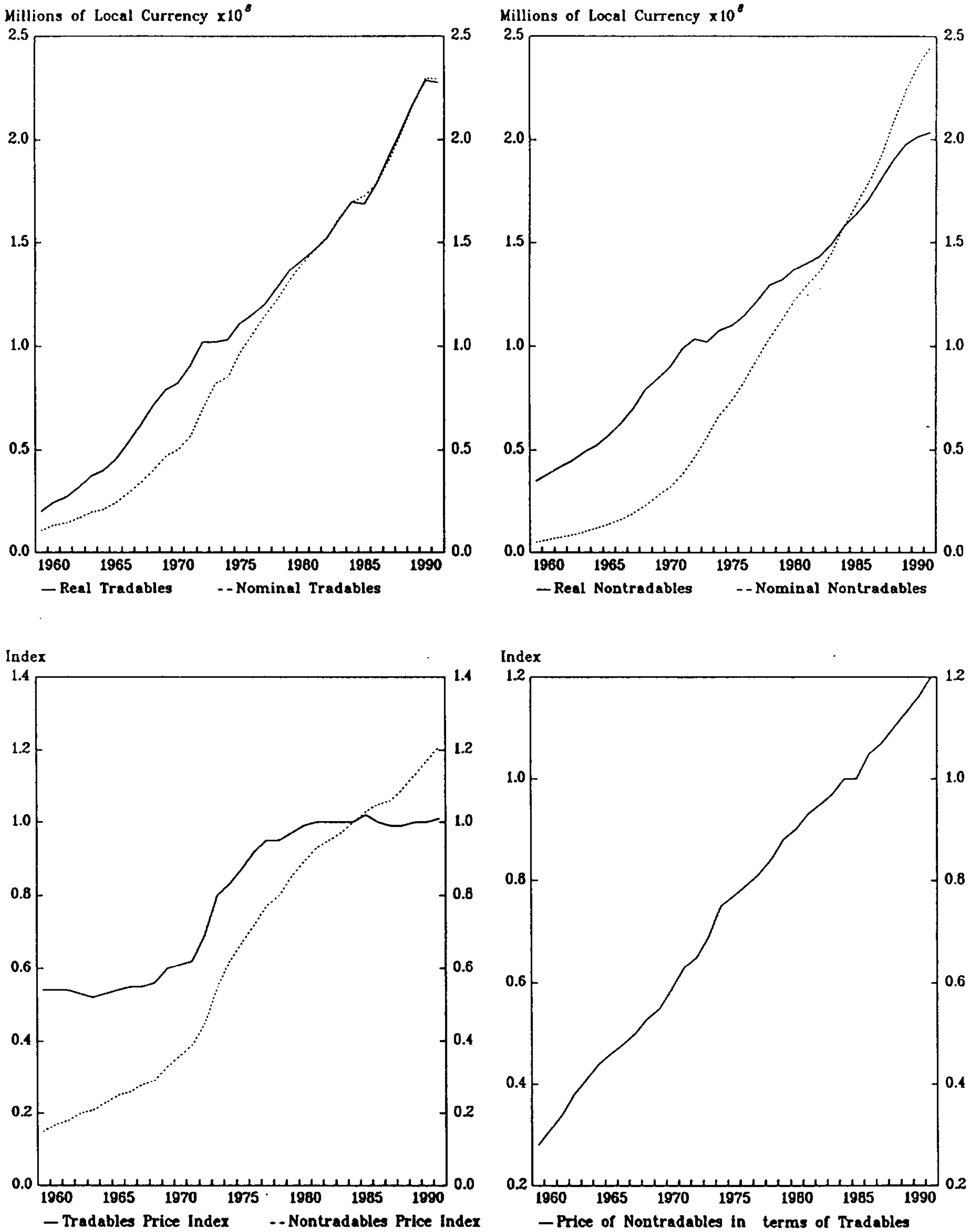


CHART A8.

SWEDEN

PRODUCTION AND PRICES FOR TRADABLES AND NONTRADABLES

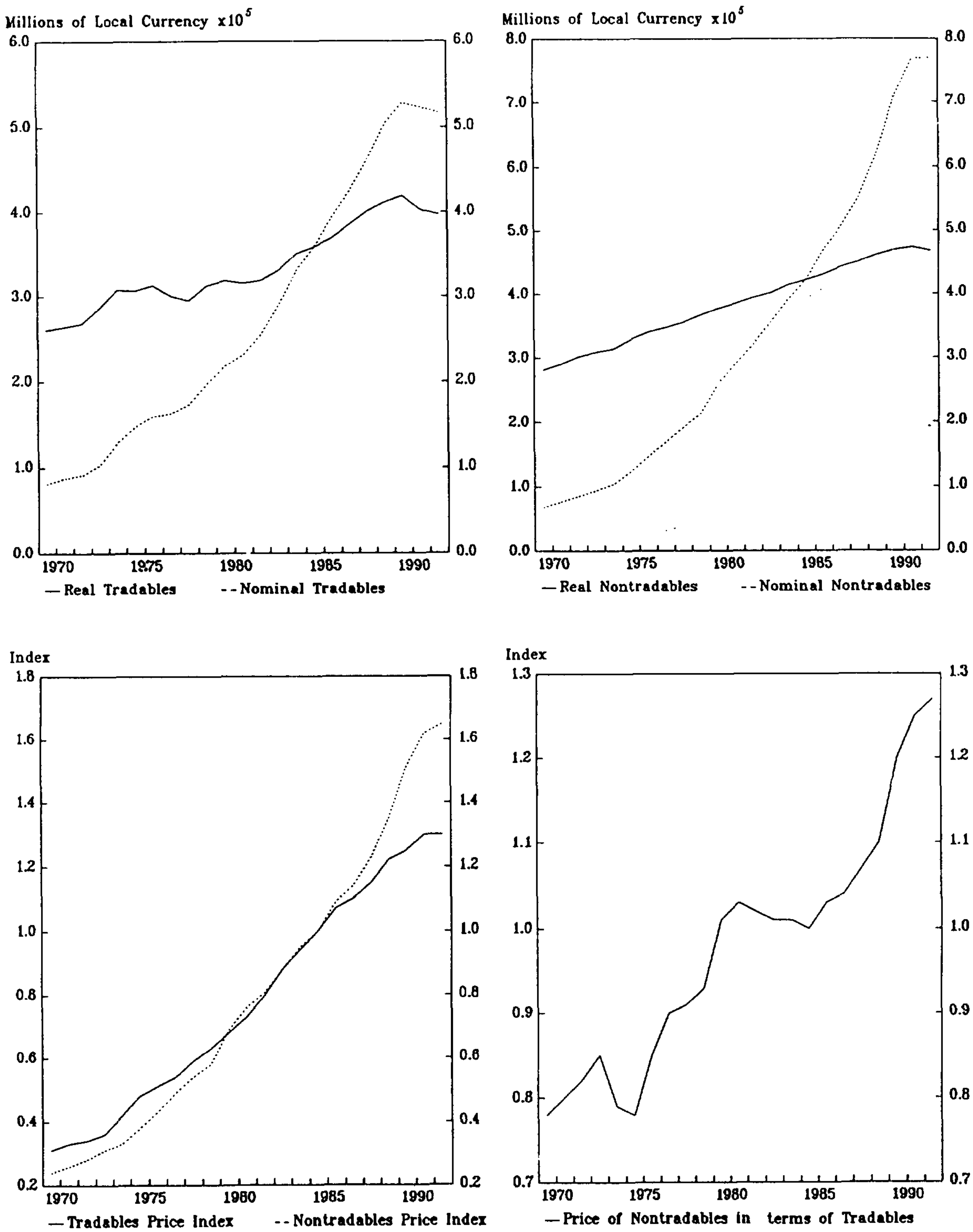


CHART A9.

UNITED KINGDOM

PRODUCTION AND PRICES FOR TRADABLES AND NONTRADABLES

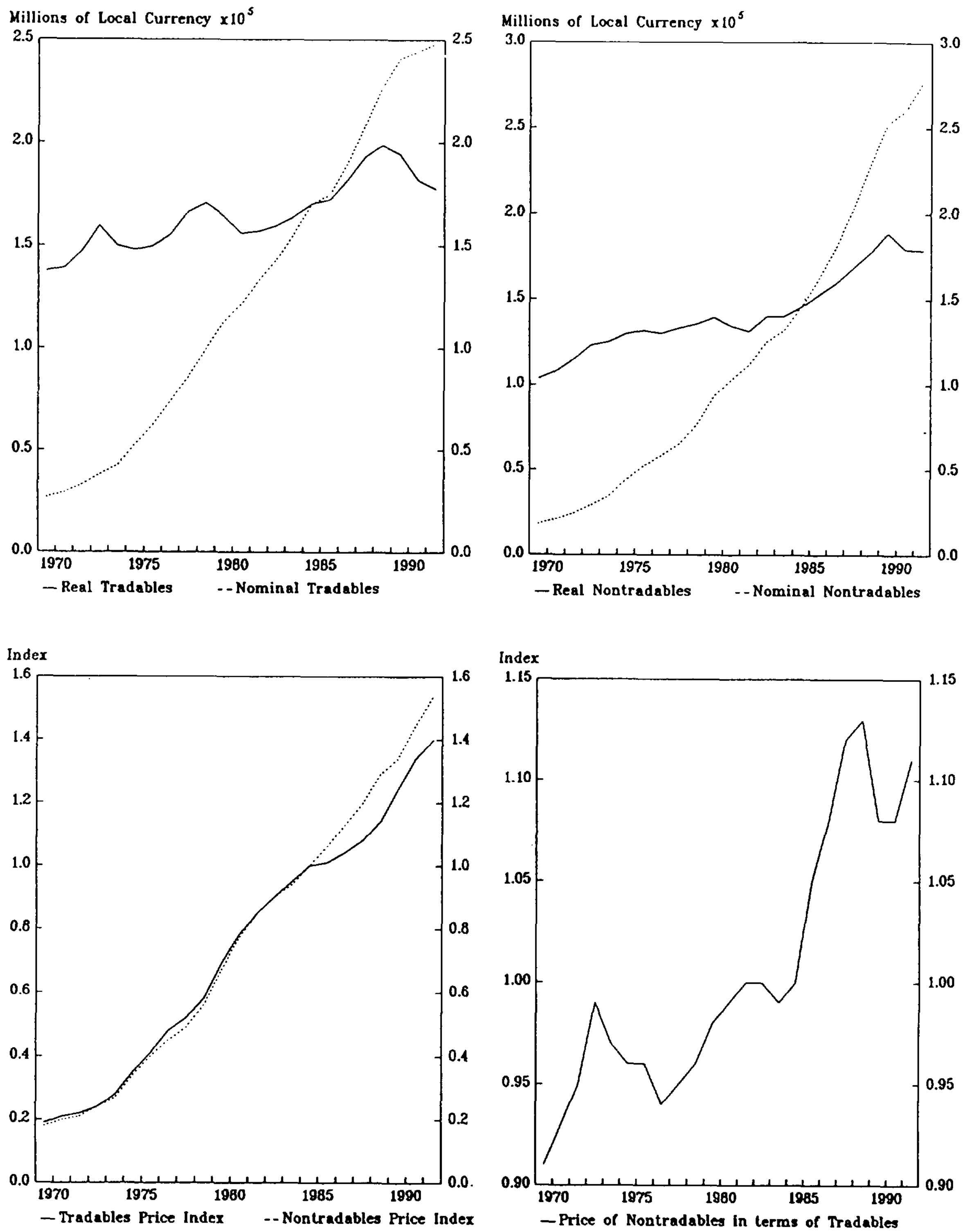


CHART A10.

UNITED STATES

PRODUCTION AND PRICES FOR TRADABLES AND NONTRADABLES

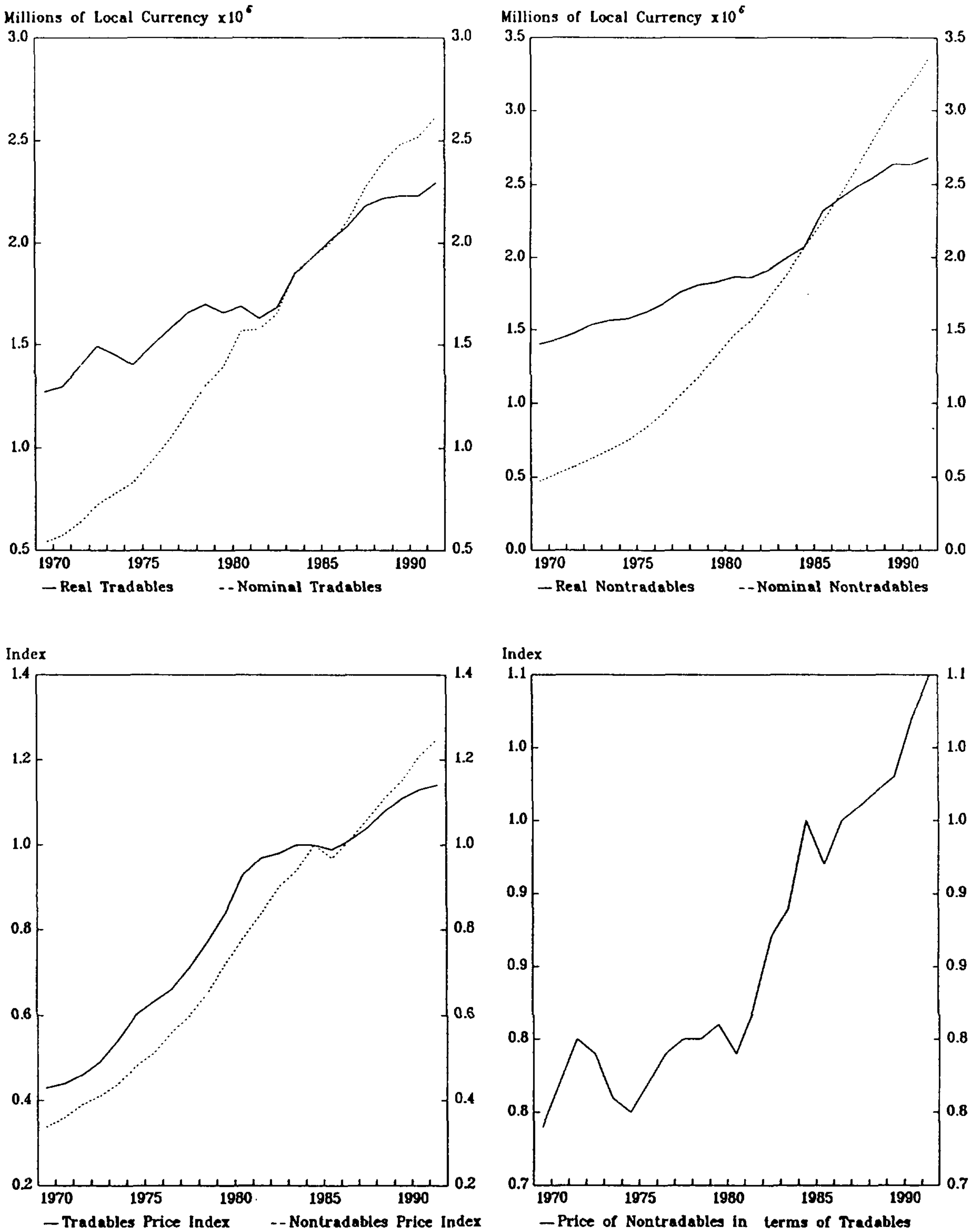
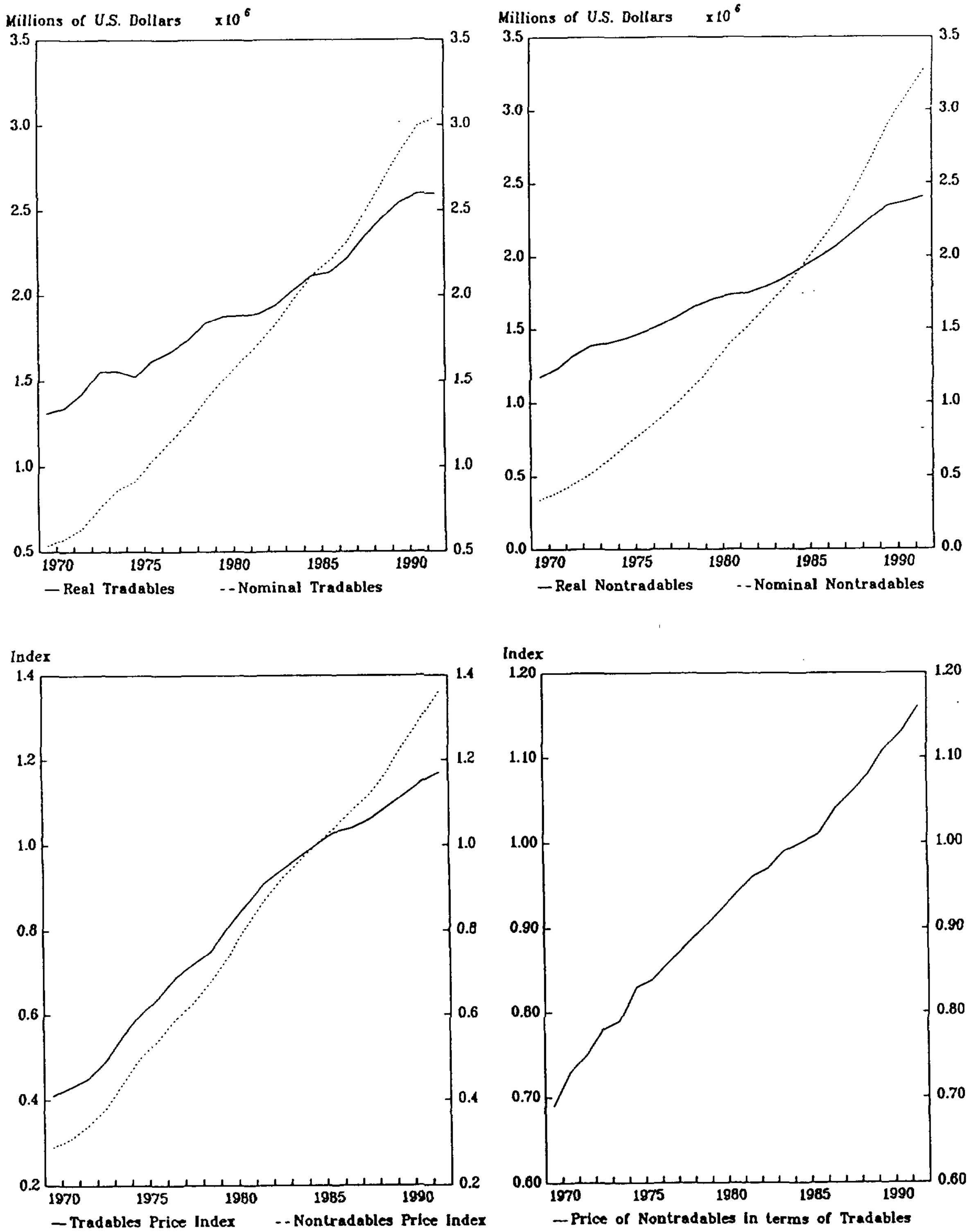


CHART A11.

REST OF WORLD VIS-A-VIS THE UNITED STATES 1/

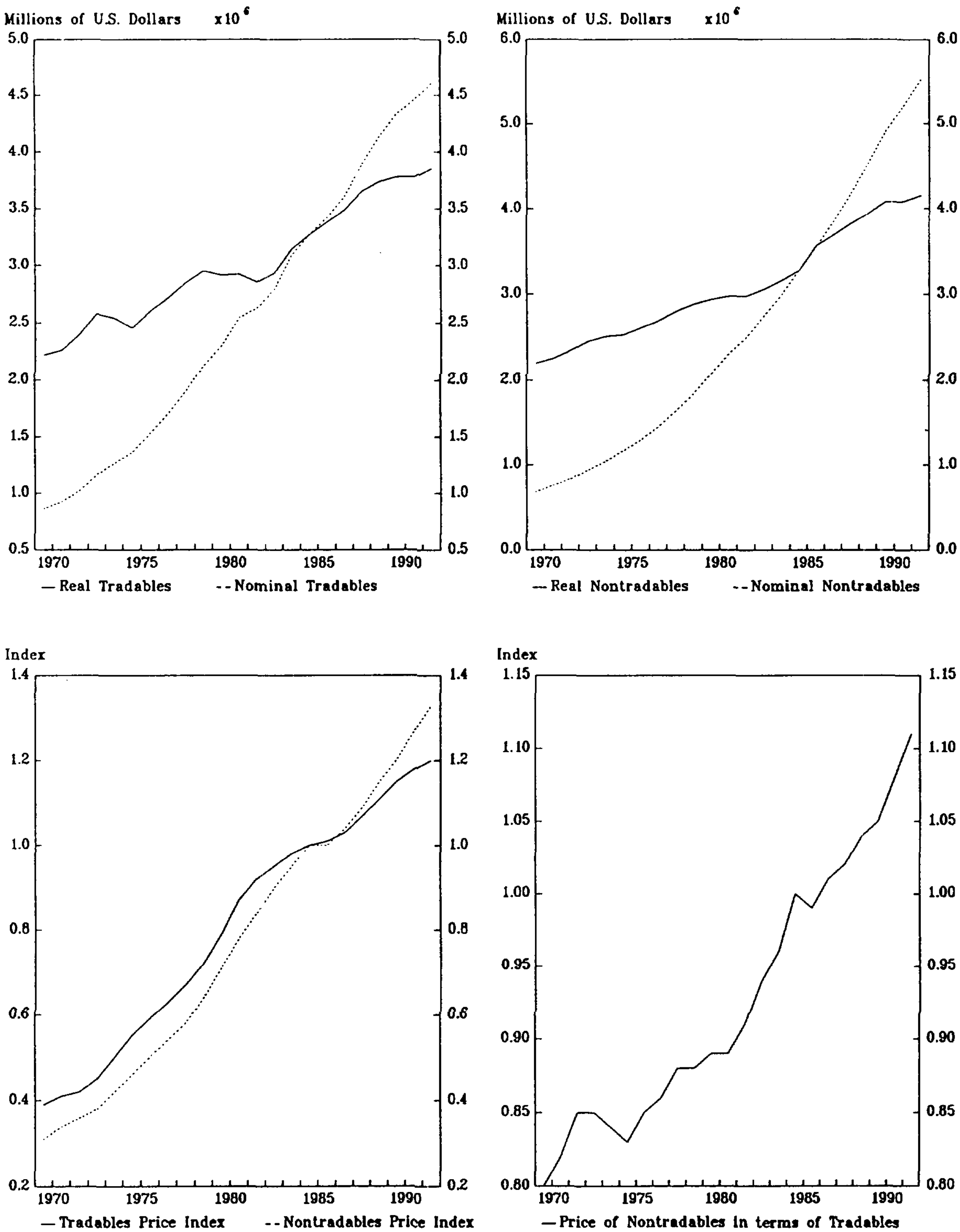
PRODUCTION AND PRICES FOR TRADABLES AND NONTRADABLES



1/ The rest of the world comprises Belgium, Canada, Germany, Italy, Japan, Sweden, and the United Kingdom.

CHART A12.

REST OF WORLD VIS-A-VIS JAPAN 1/
PRODUCTION AND PRICES FOR TRADABLES AND NONTRADABLES

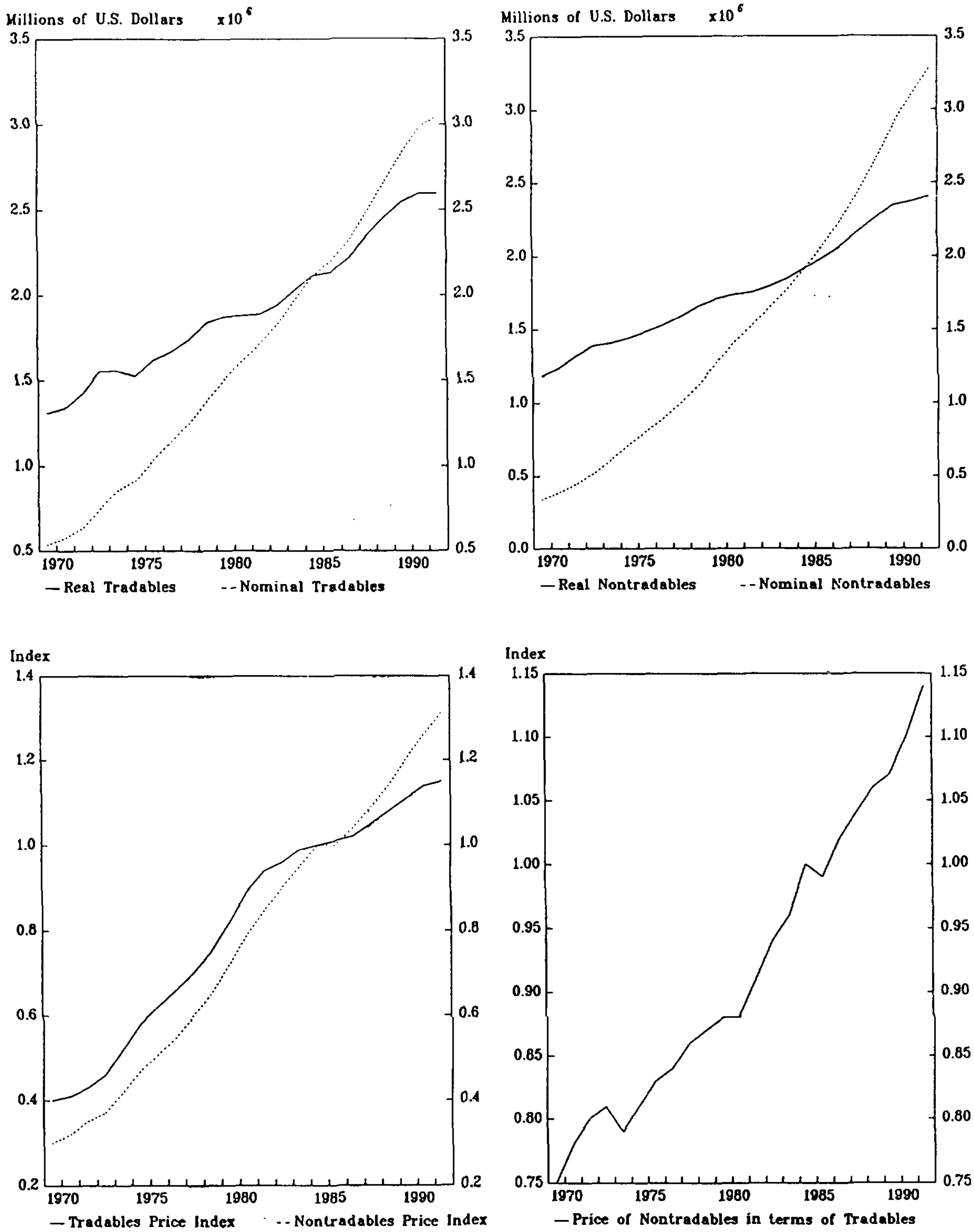


1/ The rest of the world comprises Belgium, Canada, Germany, Italy, Sweden, the United Kingdom, and the United States.

CHART A13.

REST OF WORLD VIS-A-VIS GERMANY 1/

PRODUCTION AND PRICES FOR TRADABLES AND NONTRADABLES



1/ The rest of the world comprises Belgium, Canada, Italy, Japan, Sweden, United Kingdom, and the United States.

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