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A Quantitative Examination of Current Account Dynamics in
Equilibrium Models of Barter Economies

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Abstract

This paper provides a numerical analysis of an intertemporal equilibrium model of a small open, barter economy that is subject to random shocks affecting endowments, the terms of trade, and the real interest rate. Equilibrium stochastic processes for macroeconomic aggregates are computed and their properties are compared with observed stylized facts. The model mimics the Harberger-Laursen-Metzler effect, but cannot account for a countercyclical trade balance, the variability of the real exchange rate, and the income elasticity of imports. The results also show that the correlation between the trade balance and the terms of trade, given incomplete insurance markets, is sensitive to changes in preference parameters and in the persistence of exogenous shocks.

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Summary

A frequent topic of debate in open-economy macroeconomics is the response of the external balance to exogenous fluctuations in the terms of trade. The sharp fluctuations in relative prices of traded goods that followed the oil-price shocks of the past two decades, and the subsequent sharp fluctuations in world trade, emphasized the importance of this issue and served to stimulate new research. Innovative theoretical models analyzed the relationship between terms of trade and the trade balance from a perspective based on intertemporal optimization and provided new insights into the nature of the optimal policy response to fluctuations in the terms of trade. The purpose of this paper is to provide some evidence of the empirical significance of some of these models.

The classic work of Harberger (1950) and Laursen and Metzler (1950) argued that the trade balance worsens in response to adverse developments in the terms of trade because the latter induce a decline in real income and savings--measured in terms of the international purchasing power of a country's exports. They viewed the decline in savings, which, in the absence of investment, is equivalent to worsening of the balance of trade, as an implication of Keynes' proposition that the marginal propensities to save and consume are less than unitary. Their policy recommendation was, therefore, that policies aimed at inducing an improvement in the terms of trade would result in a strengthening of the balance of trade. In the early 1980s, the Harberger-Laursen-Metzler effect was questioned by Obstfeld (1982) and Svensson and Razin (1983), who argued that, because the motive behind the less-than-unitary marginal propensity to save is the individual's desire to smooth consumption, the Harberger-Laursen-Metzler effect should be explored in a framework of explicit dynamic optimization. In such a framework, the response of the balance of trade to changes in the terms of trade depends on the public's perception regarding the persistence of fluctuations in the terms of trade. In general, if individuals expect a decline in the terms of trade to be purely transitory, the Harberger-Laursen-Metzler effect follows; if they expect it to be permanent, the effect on the trade balance is smaller and, under certain conditions, can be neutral. Hence, policies aimed at improving a country's terms of trade do not necessarily improve its trade balance.

This paper examines an intertemporal equilibrium model of a small, open barter economy that is subject to random shocks affecting endowments, the terms of trade, and the real interest rate. Equilibrium stochastic processes for macroeconomic aggregates are computed and their properties are compared with observed stylized facts. The model mimics the Harberger-Laursen-Metzler effect, but cannot account for a countercyclical trade balance, the variability of the real exchange rate, and the income elasticity of imports.

I. Introduction

This paper examines the properties of the equilibrium stochastic processes that characterize macroeconomic aggregates in an intertemporal equilibrium model of a small open, barter economy. The model is a prototype of the intertemporal equilibrium models that served as the basis for an important part of the theoretical work on current account dynamics produced in the 1980s (see, for example, Obstfeld (1981), Greenwood (1983), and Svensson and Razin (1983)). ^{1/} This theoretical literature showed that dynamic equilibrium models are potentially capable of explaining the observed empirical regularities that characterize current-account and trade-balance behavior, in the sense that comparative statics analysis results in a pattern of co-movement among macroeconomic variables that does not contradict empirical evidence. It is an interesting question whether a numerical analysis of a model of this kind would support the same view.

The pattern of co-movement between the trade balance, output, and the terms of trade is among the most widely discussed empirical regularities in open-economy macroeconomics. The correlation between the trade balance and output at constant prices is well documented as being weakly negative, while for many countries the trade balance and the terms of trade, measured as the relative price of exports in terms of imports, tend to be positively correlated. This phenomenon is known in the literature as the Harberger-Laursen-Metzler effect and it has been the subject of intense debate. ^{2/} Backus, Kehoe, and Kydland (1991b), Stockman and Tesar (1991), in the next section of this paper report correlations between the trade balance, output, and the terms of trade for large industrialized countries that are consistent with this view. The income elasticity of imports is another aspect of the co-movement between trade flows and output that has been widely studied. ^{3/} According to Marquez (1991), most of the existing empirical work in this area assumes that income elasticities are determined exogenously and it abstracts from modelling important cross-price and cross-expenditure effects. When these effects are taken into account, measured income elasticities tend to decline as the economy is opened. Marquez notes, however, that further work is needed to incorporate intertemporal considerations.

The intertemporal equilibrium framework, according to which agents wish to smooth consumption and the external balance is entirely financed by external borrowing or lending, provides the following interpretation of the co-movement between the trade balance, output, and the terms of trade. First, output and the trade balance are negatively correlated because, when

^{1/} Frenkel and Razin (1987) and Kimbrough (1987) reviewed this literature in detail.

^{2/} Three classic articles discussing the Harberger-Laursen-Metzler effect from the perspective of intertemporal equilibrium models are Obstfeld (1983), Svensson and Razin (1983), and Persson and Svensson (1985).

^{3/} For a thorough review of the literature on income elasticity of imports see Goldstein and Khan (1985).

productivity or terms-of-trade shocks exhibit enough persistence, the pro-borrowing (pro-saving) effect induced by expectations of higher (lower) future income dominates the pro-saving (pro-borrowing) effect induced by an increase (decline) in current income. Second, the terms of trade and the trade balance are positively correlated because, when the terms of trade worsen (improve), the trade balance worsens (improves) as agents borrow (save) abroad rather than adjust consumption fully in response to a temporary decline (increase) in the purchasing power of exports. The assumption of a barter economy simplifies the theoretical analysis significantly by making domestic savings identical to the balance of trade.

Implicit in this framework's interpretation of the stylized facts is the view that shocks to income, originating in productivity or terms-of-trade disturbances, are persistent enough to produce a countercyclical trade balance, while at the same time terms-of-trade shocks are sufficiently transitory to result in a positive correlation between the trade balance and the terms of trade. This is a difficult empirical question. Attempts at producing econometric evidence on the empirical relevance of equilibrium models of barter economies, as in Hercowitz (1986) and Ostry and Reinhart (1991), have shown that while this framework provides some very helpful insights, it also suffers from noticeable weaknesses. The problem is that, without explicitly modelling both terms-of-trade and output disturbances as random shocks in a choice-theoretic setting with uncertainty, and without computing the equilibrium stochastic process of the resulting model, it is difficult to establish whether intertemporal equilibrium models of barter economies can mimic observed stylized facts. This is the problem that this paper tries to solve.

This paper analyzes a model that incorporates the key features of the theoretical literature on equilibrium models of the current account for small open, barter economies developed in the 1980s, particularly the work of Obstfeld (1981), Greenwood (1984), and Ostry (1988). Agents derive utility from consumption of exportable, importable, and nontradable goods, and they are endowed with fixed amounts of exportables and nontradables. Unlike most of the theoretical work, however, agents in this model face stochastic shocks affecting their endowments, the terms of trade, and the world real interest rate. The contribution of this paper is that it computes the equilibrium stochastic processes for the endogenous variables in the model, and compares their basic properties with some key stylized facts obtained from actual data. The paper shows that some of the properties of these stochastic processes differ from well-established empirical regularities, in particular the countercyclical behavior of the balance of trade. The analysis illustrates the importance of modelling investment decisions in order to explain savings and the current account, and that the observed behavior of external trade cannot be accounted for solely on the basis of consumption smoothing principles.

The emphasis that this paper gives to numerical simulations of a dynamic stochastic equilibrium model is common to recent work in open-economy macroeconomics. Backus, Kehoe and Kydland (1991a) simulated a two-

country open-economy real business cycle (RBC) model under the assumption of complete insurance markets, and found it to be consistent with some of the observed stylized facts. Backus, Kehoe and Kydland (1991b) and Stockman and Tesar (1991) extended the two-country complete-markets RBC model to a framework that examines the dynamics of the terms of trade. Mendoza (1991a) simulated a small open economy RBC model with perfect capital mobility but incomplete insurance markets, and was able to reproduce many key features of Canadian business cycles. However, an important weakness was identified in this model in that it produced close to perfect correlation between consumption, savings, and output due to insufficient intertemporal consumption substitution. The model explored in this paper is less sophisticated, as the objective is to study the dynamics of a barter economy by abstracting from modelling investment, ^{1/} but it extends previous work by incorporating a three-good structure in order to produce more realistic consumption behavior.

The assumption regarding the structure of insurance markets adopted in models of open economies is of key importance in explaining equilibrium co-movements in macroeconomic aggregates. When extended to an environment with uncertainty, most of the theoretical work of the 1980s referred to above would embody incomplete insurance markets, as this literature typically allowed only for the existence of one-period risk-free foreign assets. Following Stockman and Dellas (1986), Backus (1989) showed that if complete contingent-claim markets are introduced, the correlation between the trade balance and the terms of trade is independent from the persistence of exogenous shocks, contrary to what incomplete-markets models would predict, and is determined mainly by the size of preference parameters and the origin and magnitude of endowment shocks. However, as Cole (1988) suggested, the assumption of complete markets may be too strong because it neutralizes completely country-specific income shocks and produces pooled equilibria by effectively modelling only one type of agent. The choice of the structure of insurance markets is therefore an empirical matter which requires that the sensitivity of equilibrium co-movements to country-specific shocks vis-a-vis preference parameters be quantified in the data and in the different models. This is an ambitious task, but one contribution of this paper is that it compares the sensitivity of equilibrium stochastic processes to changes in the persistence of exogenous shocks and to changes in the intertemporal and intratemporal elasticities of substitution in a model with incomplete markets.

The paper is organized as follows. Section II provides some empirical evidence on the behavior of the trade balance, output, and the terms of trade for the seven largest industrialized countries (G-7). Section III presents the structure of the model and discusses the conditions governing

^{1/} Mendoza (1991b) analyzes the role of terms-of-trade disturbances as a driving force of business cycles in industrialized and developing countries using a model of a small open economy with two production sectors and consumption of exportables, importables, and nontradables.

optimal behavior in general equilibrium. Section IV discusses functional forms and values of relevant parameters for preferences, endowments, and the structure of financial markets. Section V presents the results of the numerical simulations, compares them with actual data, and performs sensitivity analysis. The last section presents some concluding remarks.

II. Some Stylized Facts for Industrialized Countries

Tables 1 and 2 list some of the statistical moments that have characterized fluctuations in output, the trade balance, the terms of trade, and consumption during the last thirty years in the major industrialized countries. In the prototypical model of a small open economy with endowments, fluctuations in output and the terms of trade are determined exogenously by some probabilistic process, while the behavior of the trade balance and consumption reflects the outcome of optimal intertemporal plans. Thus, the statistical moments of GDP and the terms of trade determine the nature of the stochastic process that disturbances to endowments and the relative price of exports in terms of imports must follow, while the moments of the trade balance and consumption are to be viewed as the key empirical regularities that the model attempts to mimic.

The moments reported in Table 1 show that, with the exception of Japan, there is certain regularity in the variability, co-movement, and persistence observed in GDP and the terms of trade. ^{1/} Excluding Japan, GDP fluctuates between 1.5 and 2.2 percent and the terms of trade between 3.1 and 5 percent in terms of percentage standard deviations. The first-order serial autocorrelation of GDP is between 0.44 and 0.65, and that of the terms of trade is between 0.26 and 0.55. The correlation between output and the terms of trade is very weak, in a range between -0.23 and 0.20. In contrast, output and terms-of-trade shocks are significantly larger, more persistent, and more correlated with GDP in Japan, perhaps reflecting the higher dependency on fuel imports in this country. ^{2/}

As indicated in the introduction, Table 1 shows that the trade balance is countercyclical, or acyclical as in Japan, and that there is a Harberger-Laursen-Metzler effect (i.e. that the trade balance and the terms of trade are positively correlated), except in the cases of Canada and the United States. Excluding these two countries, the correlation between the trade balance and the terms of trade is between 0.35 and 0.73. For all seven countries, the correlation between output and the trade balance ranges from 0.05 in Japan to -0.71 in Canada. The standard deviation of the balance of

^{1/} The model presented in the paper focuses on the case of a small open economy, and hence stylized facts for countries such as the United States, Germany, and Japan must be interpreted with caution.

^{2/} Japan's fuel imports in 1988 were 27 percent of all imports, while for the rest of the G-7 the share of fuel imports in total imports was between 5 percent and 13 percent.

Table 1. Statistical Properties of Output, the Trade Balance and the Terms of Trade
in the Seven Largest Industrialized Countries 1/

Country	GDP		Terms of Trade			Trade Balance			
	σ	ρ	σ	ρ	$\rho_{\text{tot},y}$	σ	ρ	$\rho_{\text{tb},y}$	$\rho_{\text{tb,tot}}$
United States	2.17	0.446	4.00	0.263	0.197	7.99	0.377	-0.277	-0.363
United Kingdom	1.98	0.524	4.41	0.551	-0.230	6.32	0.509	-0.538	0.731
France	1.49	0.654	3.46	0.341	0.287	4.43	0.132	-0.019	0.566
Germany	1.92	0.439	4.37	0.490	0.239	4.78	0.424	-0.299	0.346
Italy	2.17	0.537	5.03	0.504	0.112	8.73	0.305	-0.210	0.404
Canada	2.01	0.540	3.09	0.469	-0.034	4.75	0.394	-0.709	-0.102
Japan	3.58	0.812	10.98	0.583	0.559	10.99	0.275	0.054	0.527

1/ Data for the terms of trade and the trade balance are for the period 1960-1989, and for GDP for the period 1965-1989, expressed in per capita terms and detrended using the Hodrick-Prescott filter with the smoothing parameter set at 100, as in Backus, Kehoe and Kydland (1991b). GDP is gross domestic product at constant prices from national income accounts, the terms of trade are the ratio of U.S. dollar unit value of exports to U.S. dollar unit value of imports, the trade balance is exports minus imports of merchandise from the balance of payments deflated using import unit values (the detrended trade balance corresponds to detrended exports minus detrended imports). Source: International Monetary Fund, *International Financial Statistics* and Data Base for the *World Economic Outlook*. σ is the percentage standard deviation, ρ is the first-order serial autocorrelation, $\rho_{\text{tot},y}$ is the correlation of the terms of trade with GDP, $\rho_{\text{tb},y}$ is the correlation of the trade balance with GDP, and $\rho_{\text{tb,tot}}$ is the correlation of the trade balance with the terms of trade.

Table 2. Statistical Properties of Private Consumption in Selected Industrialized Countries 1/

Country	<u>Aggregate Consumption</u>		<u>Nontradables</u>		<u>Tradables</u>
	σ/σ_y	$\rho_{c,y}$	σ/σ_y	$\rho_{t,nt}$	σ/σ_y
United States	0.74	0.935	0.43	0.724	1.12
Italy	0.62	0.371	0.35	0.864	0.76
Canada	1.07	0.930	0.57	0.620	1.56
Japan	1.22	--	0.97	0.909	1.50

1/ σ/σ_y is the standard deviation relative to the standard deviation of output, $\rho_{c,y}$ is the correlation of consumption with output, and $\rho_{t,nt}$ is the correlation of consumption of tradables with consumption of nontradables. These moments are from Stockman and Tesar (1991), and correspond to data from the OECD *Quarterly Accounts* (Citibase for U.S. data), converted to annual data taking averages, and detrended with the Hodrick-Prescott filter using the smoothing parameter set at 400. Aggregate consumption is private final consumption, including durables and semi-durables. Consumption of nontradables is measured as the sum of expenditures on "rent, fuel, and power," and "transportation and communication". The data are for the period 1970-1988, except in the case of Italy for the period 1981-1987.

trade ranges from 4.4 percent to 11 percent, with Japan again the outlier. However, despite this relatively wide range the trade balance is always between 1 and 2 times more variable than the terms of trade. There is also some regularity in the first-order serial autocorrelation of the trade balance, which ranges from 0.13 to 0.51.

Unfortunately, despite the general uniformity in the stylized facts across countries, the basic prediction of intertemporal equilibrium models of barter economies with incomplete markets--that more (less) persistent output and terms-of-trade shocks should weaken (strengthen) the co-movement between the trade balance and output and the correlation between the terms of trade and the trade balance--is not easily identified in the data. For instance, for the United States, the country with the lowest persistence in the terms of trade and the second-lowest persistence in GDP, the data show the lowest correlation between the trade balance and the terms of trade at -0.36. For Japan, the country with the highest persistence in output and the terms of trade, the data produce the largest correlations between the trade balance and output and between the trade balance and the terms of trade.

It is possible that part of this puzzle simply reflects measurement error. Mendoza (1991b) shows that for the countries where the relevant correlation coefficients are statistically significant, the ranking of co-movements is more in line with the predictions of the model. But this puzzle may also reflect weaknesses in the design of the model. For instance, models of barter economies ignore the fact that actual trade-balance behavior does incorporate optimal investment plans. In a deterministic setup, the change in the trade balance resulting from exogenous shocks is smaller in an economy with investment than in a barter economy, for output and terms-of-trade shocks of the same size and persistence. Moreover, following some of the arguments presented in the introduction, the structure of financial markets may be "too incomplete." The model would seem to give excessive emphasis to the persistence of country-specific shocks relative to possible differences in preference parameters, which could account for cross-country differences in the relevant statistical moments. To substantiate these arguments, however, it is necessary to establish whether the model of a barter economy can mimic the observed stylized facts once the covariance structure of shocks to output and the terms of trade is defined in full, and to determine how sensitive the results are to changes in the persistence of exogenous shocks relative to changes in preference parameters.

Dynamic equilibrium models of barter economies are also concerned with the behavior of consumption. The ultimate goal of these models is in fact to explain the behavior of the trade balance on the basis of the principle of consumption-smoothing. Table 2 reproduces some statistical moments for aggregate consumption and consumption of tradables and nontradables that were reported by Stockman and Tesar (1991) for four of the G-7. Given the lack of data on consumption of tradable and nontradable goods, they used information from the OECD to approximate consumption of nontradables with data on personal expenditures in some services and fuel. This evidence

suggests that the consumption of tradables and nontradables is positively correlated, in a range from 0.62 to 0.91. Consumption of nontradables is about half as variable as output, except for Japan where nontradables consumption is almost as variable as GDP, while consumption of tradables in three of the four countries listed is more variable than output. The large variability of the consumption of tradables may reflect a measurement problem common to data on aggregate private consumption. Aggregate private consumption is often found to be more variable than output, as Tables 2 illustrates, apparently in violation of the principle of consumption smoothing. It is well established, however, that once consumption of durables is subtracted, consumption becomes less variable than output and exhibits distinctly procyclical behavior. For instance, Prescott (1986) and Backus, Kehoe, and Kydland (1991a) report that consumption of nondurables is between 0.3 and 0.6 times as variable as output in quarterly detrended data of the United States, with a coefficient of correlation with output ranging from 0.66 to 0.81. Mendoza (1991a) finds that for Canada the ratio of the standard deviation of nondurables consumption to the standard deviation of GDP is 0.87 in annual data, and the GDP correlation of nondurables consumption is 0.59.

III. The Intertemporal Equilibrium Prototype of a Small Open, Barter Economy

Consider an economy inhabited by infinitely lived individuals with identical preferences and whose objective is to maximize expected lifetime utility. Individuals consume three goods. Two goods are tradable, an exportable or home good x and an importable or foreign good f , and one good represents nontradable goods and services n . There are fixed endowments of exportables, X , and nontradables, N , with the relative price of exportables in terms of importables (i.e. the terms of trade) and the relative price of nontradables in terms of importables denoted as p^x and p^n respectively. There is also a perfectly competitive world capital market to which individuals have free access. In this market, agents borrow or save as much as they want by buying or selling foreign financial assets, a , denominated in units of the foreign good. These assets are one-period bonds that yield the world's real interest rate r^* . Individuals in this economy are small participants in international markets, and hence they formulate optimal plans by taking r^* and p^x as determined in the rest of the world. The economy experiences stochastic disturbances that affect the endowments, e^y , the terms of trade, e^p , and the world's real interest rate, e^r .

The optimization problem that describes this economy is to maximize:

$$U(x, f, n) = E \left[\sum_{t=0}^{\infty} \left\{ u(x_t, f_t, n_t) \exp \left(- \sum_{\tau=0}^{t-1} v(x_\tau, f_\tau, n_\tau) \right) \right\} \right] \quad (1)$$

with respect to the sequences $\{a_{t+1}\}_0^\infty$, $\{x_t\}_0^\infty$, $\{f_t\}_0^\infty$, and $\{n_t\}_0^\infty$, and subject to the set of constraints:

$$f_t + e_t^p p_t^x X_t + p_t^n n_t = e_t^y (e_t^p p_t^x X + p_t^n N) - a_{t+1} + a_t (1+r^* e_t^n), \quad (2)$$

for $t=0, \dots, \infty$.

Expected lifetime utility embodies a rate of time preference that increases with the level of past consumption. ^{1/} Following work by Uzawa (1968), this endogenous rate of time preference has been widely used in dynamic equilibrium models of small open economies to produce a well-defined stationary equilibrium (see Obstfeld (1981) and Engel and Kletzer (1989) for examples of deterministic models, and Mendoza (1991a) for an application to a model with uncertainty).

Optimal consumption and savings plans are characterized by familiar conditions:

$$\frac{U_f(t)}{\exp(-v(t)) E_t[U_f(t+1)]} = (1+r^* e_t^n) \quad (3)$$

$$\frac{U_x(t)}{U_f(t)} = e_t^p p_t^x, \quad (4)$$

$$\frac{U_n(t)}{U_f(t)} = p_t^n. \quad (5)$$

These conditions have the usual interpretation, except that the lifetime marginal utilities of foreign goods, $U_f(t)$, exportable goods, $U_x(t)$, and nontradables, $U_n(t)$, include a term that accounts for the impact of changes in current consumption on the rate of time preference at which future consumption is discounted. Condition (3) sets the intertemporal marginal rate of substitution in consumption of imports equal to their intertemporal relative price, $(1+r^* e_t^n)$, and conditions (4) and (5) set the intratemporal marginal rates of substitution in consumption of exportable and foreign goods, and nontradable and foreign goods equal to their corresponding relative prices.

The effects of temporary and permanent changes in the terms of trade on consumption and the trade balance in a framework similar to this have been analyzed extensively in the theoretical literature. Researchers used comparative statics and duality to show how the parameters describing preferences interact to affect the dynamics of macroeconomic aggregates. The findings of some of this literature, which focused mostly on

^{1/} According to Epstein (1983), the functions $u(\cdot)$ and $v(\cdot)$ should satisfy the following conditions:

$u(\cdot) < 0$, $u'(\cdot) > 0$, $u'(0) = \infty$, $\ln(-u(\cdot))$ convex, and $v(\cdot) > 0$, $v'(\cdot) > 0$, $v''(\cdot) < 0$, and $u'(\cdot) \exp(v(\cdot))$ nonincreasing.

deterministic, two-period models, provide helpful insights to understand the forces at work in the infinite-horizon, stochastic setup studied here, and thus it is worthwhile to review them briefly.

In an infinite-horizon, deterministic setup with an endogenous rate of time preference as in (1), Obstfeld (1981) showed that the trade balance improves in response to a permanent worsening in the terms of trade. He interpreted this as an argument against the Harberger-Laursen-Metzler effect. Later, Svensson and Razin (1983) proved that in a model where agents live for two periods and all goods are tradable, a temporary fall in the terms of trade results in a worsening of the balance of trade, while the response of the trade balance to a permanent decline in the terms of trade is ambiguous and depends on the rate of time preference. Thus, the Harberger-Laursen-Metzler effect could be theoretically plausible. In a two-period model with nontradable goods and where agents do not consume exportables, Greenwood (1984) showed that the results of Svensson and Razin still hold under certain assumptions, and identified the parameters that are key for explaining the co-movement between macroeconomic variables. According to his analysis, the magnitude of the response of the trade balance to a transitory terms-of-trade shock depends on the cross-price elasticities of imports with respect to the relative price of nontradables in the two periods, and on the marginal propensity to consume imports. Using a two-period model where agents consume exportables, Ostry (1988) determined that the co-movement between the trade balance and temporary changes in the terms of trade depends on the intertemporal elasticity of substitution in aggregate consumption, the intratemporal elasticity of substitution between importables, exportables, and nontradables, the shares of total expenditure allocated to each of the three goods, the fraction of the endowment of importables that is consumed, and the average propensity to save. The direction of the co-movement can be positive or negative depending on the relative size of these parameters.

The previous discussion shows that theoretical predictions regarding equilibrium co-movements in dynamic optimizing models of open economies are very general. In contrast, the numerical analysis undertaken in the next sections attempts to provide more specific results by first establishing realistic values for the relevant preference parameters, and then producing equilibrium co-movements resulting from this set of parameters that can be compared with actual stylized facts. The objective is to examine the potential empirical relevance of the model by assessing whether realistic parameters produce realistic equilibrium co-movements.

IV. Quantitative Analysis

For purposes of the quantitative analysis, the functions $u(\cdot)$ and $v(\cdot)$ in the lifetime utility function (1) are assumed to have the following form:

$$u(x, f, n) = \frac{\left((x^\alpha f^{1-\alpha})^{-\mu} + n^{-\mu} \right)^{-\frac{1}{\mu}}}{1-\gamma}, \quad (6)$$

$$v(x, f, n) = \beta \ln \left(1 + \left((x^\alpha f^{1-\alpha})^{-\mu} + n^{-\mu} \right)^{-\frac{1}{\mu}} \right), \quad (7)$$

$$0 \leq \alpha \leq 1, \mu > -1, \gamma > 1, \beta > 0.$$

These functional forms assume that there is a constant elasticity of substitution between tradables and nontradables, $(1/(1+\mu))$, and that the shares of expenditures on exportables and importables in total expenditure on tradables, measured using the price of importables as numeraire, are fixed at α and $1-\alpha$ respectively. The intertemporal elasticity of substitution is given by $1/\gamma$, and β approximates the elasticity of the rate of time preference with respect to the CES utility derived from tradables and nontradables.

Given (6) and (7), numerical solutions to the optimization problem (1) can be obtained by applying an algorithm to a simplified dynamic programming formulation of the problem. Two steps are involved in the derivation of the functional equation that characterizes the dynamic program. First, since nontradables are available each period in fixed supply $e_t^Y N$, market-clearing dictates that $n_t = e_t^Y N$; thus, (5) determines the relative price of nontradables, p_t^n , that adjusts as necessary to ensure that each period n_t is set optimally to clear the market. With the functional forms (6) and (7), it is easy to show that the equilibrium relative price of nontradables is:

$$p_t^n = \frac{(e_t^Y N)^{-\mu-1}}{(x_t^\alpha f_t^{1-\alpha})^{-\mu-1} (1-\alpha) x_t^\alpha f_t^{-\alpha}}. \quad (8)$$

This expression determines the equilibrium relative price of nontradables once the output shock e_t^Y is observed and the optimal plans for consumption of exportables and importables are known. The equilibrium relative price of nontradables is the key determinant of the real exchange rate. 1/

The second step takes advantage of the fact that with the functional forms (6) and (7), in particular the Cobb-Douglas structure of preferences regarding exportables and importables, one can use (4) to express x_t as a function of f_t in equilibrium ($x_t(f_t)$) in the following manner:

1/ The stochastic equilibrium process of the real exchange rate E is given by $(p^n)^{\omega n}$, where ωn is the weight of nontradables in the domestic economy's price index. This requires that purchasing power parity holds for tradable goods and that the relative price of nontradables abroad is nonrandom.

$$\lambda_t = \left(\frac{\alpha}{1-\alpha} \right) \left(\frac{f_t}{e_t^p p_t^x} \right). \quad (9)$$

With these simplifications in mind, and assuming that the disturbances e^y , e^p , and, e^r are first-order Markov processes, the dynamic programming problem that determines the equilibrium stochastic process of the model is:

$$V(a_t, e_t) = \max_{a_{t+1}} \left\{ \frac{[(\lambda(f_t) * f_t^{1-\alpha})^{-\mu} + (e_t^y M)^{-\mu}]^{-\frac{(1-\gamma)}{\mu}}}{(1-\gamma)} + \left(1 + [(\lambda(f_t) * f_t^{1-\alpha})^{-\mu} + (e_t^y M)^{-\mu}]^{-\frac{1}{\mu}} \right)^{-\beta} E[V(a_{t+1}, e_{t+1})] \right\},$$

s. t.

$$f_t = (1-\alpha)[e_t^p p_t^x e_t^y \lambda + (1+r^* e_t^r) a_t - a_{t+1}], \quad (10)$$

$$e_t, e_{t+1} \in [e^p, e^y, e^r], \quad a_t, a_{t+1} \geq \Delta \text{ and } f_t \geq 0.$$

This functional equation has the following interpretation. At the beginning of each period t , agents start with a certain stock of net foreign assets, or debt, and observe the realizations of the shocks affecting the endowments, the terms of trade, and the world's real interest rate. Thus, given the constraints, the state of the economy is fully described by the pair (a_t, e_t) , where e_t is the triple (e_t^y, e_t^p, e_t^r) . Individuals must then formulate optimal, state-contingent plans with regard to consumption of importables, f_t , and the acquisition of foreign assets, a_{t+1} , taking into account their rational expectations with regard to future realizations of the disturbances. These optimal plans, given (8) and (9), determine the optimal equilibrium paths for consumption of exportables and the relative price of nontraded goods.

V. Solution Method and Parameter Values

A variation of the algorithm used in Mendoza (1991a), which originated in the work of Bertsekas (1976), is employed here to find a numerical solution to the dynamic programming problem (10). This algorithm defines discrete grids for the state variables and iterates on the value function and the state-transition probability matrix, taking advantage of their contraction properties, to compute the unique invariant joint limiting distribution of the state variables (a, e) in the stochastic steady state of the economy. ^{1/} The statistical moments that characterize the equilibrium stochastic processes of all macroeconomic aggregates in the model can be

^{1/} For a detailed description of this algorithm see Greenwood, Hercowitz, and Huffman (1988) and Mendoza (1991a).

easily computed once this limiting distribution is known. These moments can then be compared with moments from actual data.

In order to use the algorithm to solve the model, it is necessary to begin by setting reasonable values for the parameters that describe preferences and the stochastic structure of the shocks. Parameterization of the disturbances is simplified by assuming that the three shocks follow two-point, symmetric Markov processes according to the simple persistence rule. In any period t there are eight possible combinations of the shocks to endowments, the terms of trade, and the interest rate, ϵ_t^s for $s=1,8$, that can be observed:

$$\epsilon_t^s \in [(\bar{e}^y, \bar{e}^p, \bar{e}^r), (\bar{e}^y, \bar{e}^p, e^r), (\bar{e}^y, e^p, \bar{e}^r), (\bar{e}^y, e^p, e^r), (e^y, \bar{e}^p, \bar{e}^r), (e^y, \bar{e}^p, e^r), (e^y, e^p, \bar{e}^r), (e^y, e^p, e^r)] \quad (11)$$

The one-step transition probabilities of going from state ϵ_t^s to state ϵ_{t+1}^u are denoted as $\pi_{s,u}$ for $s,u=1,8$ and they are given by:

$$\pi_{s,u} = (1-\theta)\Pi_u + \theta\delta_{s,u} \quad (12)$$

θ governs the persistence of the disturbances, Π_u is the limiting probability of state ϵ^u , and δ is the Kronecker delta ($\delta_{s,u}=1$ if $s=u$ and 0 otherwise). For each starting state ϵ^s , the one-step transition probabilities must be between 0 and 1 and must add up to unity. The symmetry conditions are as follows:

$$\bar{e}^y = -e^y = e^y, \bar{e}^p = -e^p = e^p, \bar{e}^r = -e^r = e^r, \quad (13)$$

$$\begin{aligned} \Pi_{(\bar{e}^y, \bar{e}^p, \bar{e}^r)} &= \Pi_{(e^y, e^p, e^r)}, \quad \Pi_{(\bar{e}^y, \bar{e}^p, e^r)} = \Pi_{(e^y, e^p, \bar{e}^r)}, \\ \Pi_{(\bar{e}^y, e^p, \bar{e}^r)} &= \Pi_{(e^y, \bar{e}^p, e^r)}, \quad \Pi_{(\bar{e}^y, e^p, e^r)} = \Pi_{(e^y, \bar{e}^p, \bar{e}^r)}. \end{aligned} \quad (14)$$

Under these assumptions, and assuming also that each shock has an exponential representation--so that e^y , e^p , and e^r are redefined as $\exp(e^y)$, $\exp(e^p)$, and $\exp(e^r)$ respectively--the variability, co-movement and persistence of the shocks are given by:

$$\begin{aligned} \sigma_{e^y} &= e^y, \quad \sigma_{e^p} = e^p, \quad \sigma_{e^r} = e^r, \\ \rho_{e^y, e^p}(1) &= \rho_{e^p, e^r}(1) = \rho_{e^r, e^y}(1) = \theta, \end{aligned} \quad (15)$$

$$\begin{aligned} \rho_{e^y, e^p} &= 1 - 4[\Pi(e^3) + \Pi(e^4)], \quad \rho_{e^y, e^r} = 1 - 4[\Pi(e^2) + \Pi(e^4)], \\ \rho_{e^p, e^r} &= 1 - 4[\Pi(e^2) + \Pi(e^3)]. \end{aligned}$$

The percentage standard deviations, σ , are given by the size of each disturbance, the first-order serial autocorrelation, $\rho(1)$, is forced to be the same for the three shocks by the simple persistence rule and is given by θ , the contemporaneous correlations are determined by the structure of limiting probabilities assigned to each state ϵ^u .

The empirical regularities documented in Table 1 provide the basic information necessary to assign values to the moments describing the stochastic processes of the endowments and the terms of trade. For interest-rate shocks, the moments have been selected following Barro and Sala-i-Martin (1990). ^{1/} Considering averages excluding Japan, where the stylized facts show larger and more persistent fluctuations in macroeconomic aggregates than in the rest of the G-7, the data suggest that reasonable parameter values for the stochastic components of the model are:

$$\sigma_{e^y} = 1.96, \sigma_{e^p} = 4.06, \sigma_{e^r} = 1.50,$$

$$\rho_{e^y}(1) = \rho_{e^p}(1) = \rho_{e^r}(1) = 0.5,$$

(16)

$$\rho_{e^y, e^p} = 0.095, \rho_{e^y, e^r} = 0.191, \rho_{e^p, e^r} = -0.404,$$

$$X = 1.0, N = 0.594, r^* = 0.04.$$

Without loss of generality, the mean of the endowment of exportables is set at unity, while the mean of the endowment of nontradables, N , is determined so as to ensure that in the deterministic steady state the ratio of nontradable to tradable expenditures is equal to the average observed in actual data for 13 industrialized countries, 0.87 (see Table 3). The average world real interest rate r^* is the mean real rate of return on a risk free asset typical of real business cycle models.

Values for the parameters in the functional forms (6)-(7) are selected using cross-sectional data for 1975 from a sample of 13 industrialized countries reported in Kravis, Heston, and Summers (1982) and UNCTAD (1987), as summarized in Table 3, in combination with the theoretical implications of the model and the estimates obtained in some of the relevant empirical literature. The parameters are set as follows:

$$\gamma = 1.5, \mu = 0.35, \alpha = 0.72, \beta = 0.432.$$

(17)

^{1/} These authors estimated the standard deviation of the world's expected real interest rate (r_w^e) at 1.5 percent. The correlations between e^y and e^r , and e^p and e^r were approximated with estimates of the correlation between r_w^e and the investment-output ratio, and the negative of the correlation between r_w^e and the price of oil, obtained with the regression coefficients of the corresponding variables in Column (1) of Table 2 and the standard deviations in Table 1 of their paper.

Table 3. Industrial Countries: Selected Data on the Composition of Consumption
Expenditures and Imports, 1975 1/

Country	(1) Relative expenditure nontradable/tradable goods	(2) Relative prices nontradable/tradable goods (index, US=100)	(3) Imports of consumer goods as a percent of total imports	(4) Imports of consumer goods as percentage of expenditure on tradables
Japan	0.90	89.3	25.1	11.0
Austria	0.74	81.6	35.4	24.9
Belgium <u>2/</u>	0.74	88.0	36.1	53.9
Denmark	1.15	74.5	32.9	31.7
France	0.83	77.1	31.7	15.7
Germany	0.79	81.7	39.6	22.4
Ireland	0.97	68.5	38.6	46.4
Italy	0.88	62.7	29.3	15.7
Luxembourg	0.94	81.2	--	--
Netherlands	0.64	92.2	38.4	48.7
Spain	0.81	62.1	26.0	9.5
United Kingdom	1.03	70.7	39.9	28.3
United States	0.74	100.0	28.3	5.5
mean <u>3/</u>	0.87	77.5	35.4	28.0

1/ Columns (1) and (2) correspond to the ratios of column (8) to column (9) in Tables 6-10 and 6-12 of Kravis, Heston, and Summers (1982). Column (3) is the sum of the shares of imports of food and manufactures (excluding chemical products and machinery and equipment) in total imports from UNCTAD (1987) pp.158-179. Column (4) is generated by applying the shares in Column (3) to data on total imports from UNCTAD (1987), and then using the U.S. dollar amount of imports of consumer goods to produce the shares of imports in consumption of tradables with data on population, private consumption, exchange rates, and share of tradables in total private consumption, from Tables 1-2, 1-7, and 6-10 in Kravis, Heston, and Summers (1982).

2/ For Columns (3) and (4) Belgium includes Luxembourg.

3/ Excluding the United States which is the base for the purchasing power correction in Kravis, Heston, and Summers (1982).

The value of the coefficient of relative risk aversion, γ , is in the range of existing estimates, and is in line with values that real business cycle models have found effective to mimic key stylized facts (see Backus, Kehoe, and Kydland (1991a), Greenwood, Hercowitz, and Huffman (1988), and Mendoza (1991a)). The values of μ and α are set using the information in Table 3. Columns (1) and (2) in this table list indices of relative consumer expenditures and relative prices for traded and nontraded goods produced with the data from Tables 6-10 and 6-12 in Kravis, Heston, and Summers (1982). As in Stockman and Tesar (1991), μ is determined by regressing the logarithm of relative expenditures on the logarithm of relative prices and logged per capita GDP adjusted for purchasing power (also from Tables 6-10 in Kravis, Heston and Summers). This regression produces a point estimate of the elasticity of substitution between tradable and nontradable goods, $(1/(1+\mu))$, of about 0.74 with a standard error of 0.438. 1/ The share of domestic tradable goods in total consumer expenditure on tradables, α , is set by obtaining an estimate of its complement, the share of consumer good imports in total tradable consumer expenditures $1-\alpha$. Column (3) of Table 3 lists the fraction of total imports pertaining to imports of consumer goods obtained from UNCTAD (1987), and this is combined with data from Kravis, Heston, and Summers (1982) to estimate $1-\alpha$ for each of the 13 countries in Column (4) of the Table, resulting in an average $1-\alpha$ equal to 0.28. 2/

Once the values of X , r^* , γ , μ , and α are known, a system of four simultaneous equations determines β and N , and the deterministic steady-state equilibrium of p^N and a . The four equations are: (a) the stationary equilibrium condition that equates the rate of time preference with r^* , (b), the marginal rate of substitution between nontradable and importable goods in the steady state, (c) the ratio of net factor payments to output measured in units of importables $\phi=r^*a/(p^X X+p^N N)$, and (d), the ratio of expenditure on nontradables to expenditure on tradables in the steady state also measured in units of importables $\Omega=p^N N/(p^X X+r^*a)$. To solve these equations, p^X is assumed to be equal to 1 in the steady state, and ϕ and Ω are set using cross-country and time-series averages from Tables 3 and 4. Column (1) in Table 3 shows that the average of Ω for 13 industrialized countries is 0.87, and the fifth column of Table 4 shows that the cross-section mean of ϕ for time-series averages of the G-7 is -0.18. 3/

1/ Stockman and Tesar (1991) use a sample that includes 17 developing countries. Their point estimate of the elasticity of substitution is 0.44 with a standard error of 0.225.

2/ See Table 3 for details.

3/ Given that Canada's relatively large and negative ϕ dominates the average for the G-7, ϕ is set at zero for purposes of the simulation analysis so that it reflects more closely the typical ratio of net factor payments to GDP in industrial countries.

Table 4. Statistical Properties of Net Factor Payments and GDP at Import Prices
in the Seven Largest Industrialized Countries 1/

Country	Net Factor Payments (r^*a)				GDP at Import Prices (y_m)			
	σ	ρ	$\rho_{r^*a,tot}$	r^*a/y	σ	ρ	$\rho_{y_m,tb}$	$\rho_{y_m,tot}$
United States	5.08	0.105	0.375	0.69	9.07	0.545	-0.569	0.847
United Kingdom	6.41	0.118	-0.011	0.92	6.95	0.438	0.346	0.771
France	3.45	0.024	0.249	0.04	7.14	0.378	0.417	0.873
Germany	8.86	-0.105	0.272	0.15	8.72	0.624	0.217	0.876
Italy	4.45	-0.676	-0.969	-0.93	10.58	0.578	0.302	0.958
Canada	14.54	0.599	-0.199	-2.27	3.54	0.403	0.161	0.065
Japan	14.74	0.582	0.735	0.15	18.15	0.572	0.522	0.972

1/ Data are for the period 1965-1989 (except net factor payments for the United States, France, and Italy where the series start in 1970, 1978, and 1984 respectively), converted into U.S. dollars and deflated by the dollar unit value of imports. The data are expressed in per capita terms and detrended using the Hodrick-Prescott filter with the smoothing parameter set at 100. Source: International Monetary Fund, *International Financial Statistics* and Data Base for the *World Economic Outlook*. σ is the percentage standard deviation, ρ is the first-order serial autocorrelation, $\rho_{r^*a,tot}$ is the correlation of net factor payments with the terms of trade, r^*a/y is the average ratio of net factor payments to GDP, $\rho_{y_m,tb}$ is the correlation of GDP with the trade balance (both at import prices), and $\rho_{y_m,tot}$ is the correlation of GDP at import prices with the terms of trade.

VI. Numerical Simulations

The discussion of the numerical simulations is divided in two parts. First, the benchmark model with parameter values set as described in the previous section is simulated, and the statistical moments characterizing equilibrium stochastic processes of macroeconomic aggregates in the model are compared with the moments from actual data listed in Tables 1, 2 and 4. 1/ This comparative analysis is illustrative of the model's ability to mimic key stylized facts, and is useful as a guide to identify weaknesses in the design of the model. The second part is an analysis of sensitivity of the properties of the equilibrium stochastic processes to changes in the persistence of the disturbances, the intertemporal elasticity of substitution in consumption, and the intratemporal elasticity of substitution between tradable and nontradable goods. This sensitivity analysis examines the relevance of key predictions obtained in the theoretical analysis of deterministic, two-period models. It also sheds some light on the extent to which incomplete markets emphasize the role of country-specific shocks, and the possibility that differences in preference parameters may account for observed differences in stylized facts across countries.

1. The benchmark model

Table 5 lists some of the statistical moments that characterize the equilibrium co-movements of macroeconomic aggregates in the benchmark model. As noted above, the model's ability to mimic some of the cyclical properties of consumption and the balance of trade is of particular interest. The percentage standard deviation, first-order serial autocorrelation, and correlation with the terms of trade of the balance of trade are in line with the moments obtained from actual data for G-7 countries. 2/ This contrasts with the standard deviation of the trade balance in the two-country complete-markets models simulated by Backus, Kehoe, and Kydland (1991b) and Stockman and Tesar (1991) which is significantly lower than that observed in the data. Income disturbances with a coefficient of persistence $\theta=0.5$ are sufficiently transitory to re-create the Harberger-Laursen-Metzler effect--the correlation between the trade balance and the terms of trade is 0.84. However, these disturbances produce a pro-saving effect that, on average, dominates the pro-borrowing effect, and hence the model cannot mimic the countercyclical or acyclical behavior of the trade balance. The

1/ Table 4 presents statistical moments for deviations from trend in real net factor payments and real GDP measured at import prices. These variables are proxies for $e^r r^* a$ and $e^y (p^x X + p^n N)$ in the model. Notice that with output measured at import prices, the trade balance becomes weakly procyclical instead of countercyclical as in Table 1.

2/ Note that the definition of the trade balance in the model would include trade in merchandise as well as nonfactor services, whereas the measure of the trade balance taken from the balance of payments for the empirical analysis only includes merchandise trade.

Table 5. Statistical Moments of Macroeconomic
Aggregates in the Benchmark Model 1/

Variables	σ	$\sigma/\sigma_{\text{tot}}$	$\rho(1)$	ρ_{tot}	ρ_{ym}
GDP at domestic prices	1.96	0.44	0.500	0.095	0.531
GDP at import prices	2.85	0.70	0.674	0.742	1.000
Consumption	2.68	0.66	0.948	0.549	0.638
Tradables	2.46	0.61	0.921	0.231	0.782
Home goods	4.23	1.04	0.566	-0.825	-0.257
Imports	2.46	0.61	0.921	0.231	0.782
Nontradables	3.05	0.75	0.938	-0.110	0.480
Trade balance	4.41	1.09	0.549	0.836	0.484
Current account	4.04	0.99	0.486	0.949	0.745
Net factor payments	36.10	8.89	0.995	0.098	0.562
Foreign assets	39.00	9.61	0.995	0.098	0.562
Terms of trade	4.06	1.00	0.500	1.000	0.742
Price of nontradables	3.31	0.81	0.843	-0.157	0.128
Real exchange rate	1.55	0.38	0.841	-0.164	0.123
Other correlations:					
Consumption of tradables and nontradables			0.920		
Trade balance and GDP at domestic prices			0.307		
Trade balance and first lag of terms of trade			0.418		

1/ All variables are measured in terms of import prices, unless otherwise noted. For each variable, σ is the standard deviation as a percentage of the mean (except for net factor payments and foreign assets for which the mean is zero), $\sigma/\sigma_{\text{tot}}$ is the standard deviation relative to the standard deviation of the terms of trade, $\rho(1)$ is the first-order serial autocorrelation, ρ_{tot} is the correlation with the terms of trade, and ρ_{ym} is the correlation with output.

correlation of the balance of trade with GDP measured at constant import prices is 0.48, and with the standard measure of real GDP is 0.31, significantly above the actual GDP correlations reported in Tables 1 and 4. For simplicity, the standard measure of real GDP is referred to as GDP at domestic prices henceforth.

In addition to the procyclical trade balance, the model also performs poorly in mimicking the moments that characterize net factor payments abroad, with the exception of their low correlation with the terms of trade. Foreign assets in the model fluctuate too much and exhibit too much persistence to be consistent with actual data.

This weak performance in explaining some aspects of trade-balance and current-account behavior suggests that the savings mechanism operating in dynamic models of barter economies misrepresents the actual savings mechanism. In particular, actual private savings plans envisage not only consumption-smoothing and consumption-substitution adjustments through the accumulation of external assets, but they also take into account optimal investment decisions. When domestic physical capital interacts with foreign assets as a means of saving, any persistent improvement in productivity or the terms of trade produces, in addition to pro-borrowing and pro-saving effects caused by the desire to smooth and substitute consumption intertemporally, an additional pro-borrowing effect reflecting an increase in investment. Another important weakness of the savings mechanism in the model is that it ignores the influence of government behavior. Under Ricardian equivalence and non-distortionary taxation, private savings would react to changes in government expenditure in a similar fashion as they do to endowment shocks. If Ricardian equivalence breaks down and distortionary taxes are taken into account, the financing mix of fiscal policy would also affect private savings. Statistically, these shortcomings imply that actual private domestic savings cannot be well duplicated by the model because it does not capture the equilibrium covariance structure between investment, government expenditure, and the balance of trade.

The fact that more than two thirds of total imports in the typical industrialized country are capital goods, as can be inferred from Column (3) in Table 3, suggests that the exclusion of investment decisions is particularly important. For instance, in the one-good model of Mendoza (1991a), the interaction between foreign assets and domestic capital produces a countercyclical trade balance and realistic behavior in the accumulation of external assets. ^{1/} That model, however, also produces the counterfactual result that savings and consumption are close to perfectly correlated with GDP. In contrast with the one-good model, the behavior of consumption in the present model mimics some important

^{1/} Backus, Kehoe, and Kydland (1991b) make a similar argument for the case of a two-country model with complete insurance markets.

properties of actual consumption behavior. ^{1/} Aggregate consumption fluctuates less than output and the terms of trade, exhibits positive persistence, and is positively, but imperfectly, correlated with GDP. In contrast with the results in Mendoza (1991a), the three-good structure considered in this paper generates a more realistic pattern of consumption behavior that does not exhibit close to perfect correlation with output. In the model with three goods, terms-of-trade and output shocks generate not only procyclical-oriented consumption-smoothing effects, resulting from projected changes in wealth, but also consumption-substitution effects, due to changes in the relative prices of exportable and nontradable goods, that weaken the correlation between output and aggregate consumption.

The model shows that imports are 0.6 times as variable as the terms of trade, with a coefficient of contemporaneous correlation between the two variables of 0.23. The co-movement between imports and the terms of trade is in the range observed in actual data, but the variability of imports is not consistent with actual observations. The standard deviation of the deviations from trend in imports is between 1 and 2.5 times as variable as the terms of trade in G-7 countries (except in Japan where the ratio is 0.8), while the imports-GDP correlation, with output measured at import prices, ranges from -0.32 to 0.46. For the reasons discussed above, the fact that the model underestimates the variability of imports may be related to the absence of investment decisions. The implicit income elasticity of imports is 0.67. ^{2/} This is lower than the income elasticities reviewed in the survey by Goldstein and Khan (1985), which ranged from 0.76 to 2.19, and is also lower than the average income elasticities estimated by Marquez (1991). However, the income elasticity at 0.67 is closer to the point estimates Marquez reported for 1987. He argued that the fall observed in these income elasticities during the 1980s reflects the opening of the economy, in a framework that incorporates cross-price and cross-expenditure effects, so the lower elasticities can be viewed as being more compatible with the free-trade environment assumed in the model. Moreover, the income elasticity obtained in the model considers not only cross-price and cross-expenditure elements at a point in time, but it also takes into account intertemporal effects. These effects seem to reinforce intratemporal cross-price and cross-expenditure effects and thus result in a lower income elasticity.

With respect to the real exchange rate and the J-curve dynamics of the co-movement between the trade balance and the terms of trade the model produces mixed results. The fluctuations of the real exchange rate in the model, which measure 1.6 percent in terms of standard deviation, seem small compared with existing evidence. For instance, Mussa (1990) reports

^{1/} Recall from Section II that, excluding durables, the variability of consumption relative to the variability of output is between 0.3 and 0.9 and the GDP correlation of consumption is between 0.6 and 0.8.

^{2/} This elasticity of imports (im) with respect to GDP (y) is estimated as $\rho_{im,y}(\sigma_{im}/\sigma_y)[E(im)/E(y)]$.

variances of bilateral exchange rates between the United States and France, Ireland, and Canada that result in percentage standard deviations ranging from 2.2 percent to 6.3 percent. Mussa's argument that observed fluctuations in real exchange rates cannot be accounted for solely by real disturbances, and in fact reflect mainly variations in nominal exchange rates, is consistent with this result. The J-curve dynamics present in actual cross-correlations between the terms of trade and the trade balance identified by Backus, Kehoe, and Kydland (1991b) can only be partially explained in the model. The first-order autoregressive structure of the shocks implies that the correlation between the trade balance at t and the terms of trade at lag k is simply $\theta^k \rho_{\text{tot}, \text{tb}}$. The evidence documented by Backus, Kehoe, and Kydland shows that this is a good approximation for some G-7 countries, but is not for Canada and the United States. 1/

To summarize, the discussion in this section of the paper suggests that, for intertemporal equilibrium models of small open economies with incomplete insurance markets to make sense, it is important to abandon the assumption of a barter economy. As Mendoza (1991a) and Backus, Kehoe, and Kydland (1991b) argue, investment decisions play a key role in explaining the stylized facts of the trade balance in dynamic equilibrium models. The results also indicate that for consumption and savings in the model to mimic actual data, the existence of nontradable goods should be taken into account, as the work of Tesar (1990) and Stockman and Tesar (1991) suggested. Once nontradable goods are considered, consumption and output are not perfectly correlated despite the fact that the world's real interest rate is independent of decisions in the small open economy.

2. Sensitivity analysis and the role of incomplete insurance markets

Table 6 lists five statistical moments that describe the behavior of the trade balance under different assumptions regarding the first-order serial autocorrelation of the disturbances present in the model. The effects of changes in the persistence of income shocks on trade-balance behavior are consistent with the predictions from the theoretical work on dynamic equilibrium models of small open, barter economies. As the persistence of the shocks increases, both the correlation between the trade balance and the terms of trade and the correlation between the trade balance and output, measured at import prices or at domestic prices, decline. This reflects mainly the combined impact of pro-borrowing and pro-saving effects induced by the agent's desire to smooth consumption. In the limit, a purely transitory rise in the terms of trade or in the endowments generates only a pro-saving effect, and hence transitory disturbances induce a stronger correlation between output and the trade balance, and between the terms of trade and the trade balance. As the shocks exhibit more persistence, agents weigh the pro-saving effect of a contemporaneous increase in the endowments

1/ Cross-correlations between the trade balance and the terms of trade for the G-7 computed using the data employed to produce the moments in Table 1 also support this argument.

Table 6. Effects of Changes in the Persistence of Income Shocks on the Behavior of the Balance of Trade 1/

θ	σ_{tb}	$\rho(1)$	$\rho_{tb, tot}$	$\rho_{tb, ym}$	$\rho_{tb, ydp}$
0.1	4.56	0.135	0.910	0.577	0.328
0.2	4.53	0.239	0.898	0.561	0.326
0.3	4.50	0.343	0.882	0.540	0.320
0.5 <u>1/</u>	4.41	0.549	0.836	0.484	0.307
0.7	4.24	0.746	0.745	0.383	0.274
0.8	3.99	0.841	0.645	0.290	0.236
0.9	3.65	0.935	0.399	0.094	0.146

1/ θ is the first-order serial autocorrelation of the disturbances, σ_{tb} is the standard deviation of the trade balance in percent, $\rho(1)$ is the first-order serial autocorrelation of the trade balance, $\rho_{tb, tot}$ is the correlation of the trade balance with the terms of trade, $\rho_{tb, ym}$ is the correlation of the trade balance with GDP at import prices, and $\rho_{tb, ydp}$ is the correlation of the trade balance with GDP at domestic prices.

2/ Value in the benchmark simulation.

or in the purchasing power of exports, against the expectations of increased future income from which they would like to borrow. Thus, shocks with higher first-order serial autocorrelation induce less co-movement between the trade balance and output and a weaker Harberger-Laursen-Metzler effect.

The findings reported in Table 6 also show that, despite the model's ability to produce a positive correlation between the trade balance and the terms of trade, the trade balance remains procyclical regardless of the size of θ . The model cannot account for the countercyclical behavior of net exports even when $\theta=0.9$. The best the model can do is to generate a trade balance that is almost uncorrelated with output, but for this it requires excessively high persistence in the disturbances which would undermine the model's ability to mimic other key stylized facts. Thus, even though it is theoretically plausible that persistent shocks could induce a strong enough pro-borrowing effect to offset the pro-saving effect, and produce a countercyclical trade balance, the simulations show that this is not likely to be the case in practice. Consumption-smoothing alone is not sufficient to explain the observed behavior of the trade balance.

As noted in the introduction, the fact that the persistence of domestic income shocks affects the equilibrium stochastic process of the trade balance is an implication of the limited risk-sharing possibilities imposed by the incompleteness of insurance markets. When there are complete markets, the persistence of domestic disturbances has no effect on the equilibrium co-movements of the trade balance. In this context, the moments listed in Table 6 are illustrative of the extent to which the role of domestic shocks is emphasized by a model that assumes incomplete markets. Clearly, at the extremes θ becomes a critical determinant of trade-balance behavior, but as long as θ is inside the range from 0.3 to 0.7 it does not seem that changing the persistence of the disturbances has major effects on the variability of the trade balance or its correlations with the terms of trade and output. This is not the case for the first-order serial autocorrelation, which is always close to the value of θ . Nevertheless, it is also the case in two-country models with complete markets that the persistence of endogenous variables reflect very closely the persistence of technology shocks, as Backus, Kehoe, and Kydland (1991b) noted.

A problem emerges because within the range $0.3 \leq \theta \leq 0.7$, which is the range consistent with most actual observations, the model with incomplete markets mimics some of the actual properties of the trade balance and consumption which models with complete markets also mimic. ^{1/} Thus, actual trade-balance behavior seems to be compatible with two different structures of financial markets. This is consistent with the findings of Cole and Obstfeld (1991). If competitive allocations are not significantly affected by the degree of completeness of financial markets, it will be

^{1/} In this context the inability of the barter economy to mimic the countercyclical trade balance is irrelevant, since Mendoza (1991a) shows that in a one-good model with investment the trade balance is countercyclical.

difficult to distinguish whether complete- or incomplete-markets models reflect more closely the true nature of world financial markets.

These simulations also suggest that the view that dynamic models of barter economies with incomplete markets emphasize the persistence of exogenous shocks because they deal with experiments that only apply to comparing deterministic equilibria, as Backus (1989) suggested, may be somewhat misleading. By adapting the Harberger-Laursen-Metzler literature of the early 1980s to a setting with uncertainty, the analysis undertaken here shows that the predictions based on deterministic models are applicable to the equilibrium co-movement between the terms of trade and the trade balance. The reason why the persistence of domestic income shocks affects the behavior of the trade balance is because of the incompleteness of insurance markets, not because of the presence or absence of uncertainty.

The differences that emerge in the pattern of equilibrium dynamics between models with incomplete markets and models with complete markets can be illustrated further by studying the effects of changes in preference parameters. Tables 7 and 8 report the results of sensitivity analysis for changes in the intertemporal elasticity of substitution in consumption ($1/\gamma$) and changes in the intratemporal elasticity of substitution between consumption of tradable and consumption of nontradable goods ($1/(1+\mu)$) in an incomplete-markets model.

Table 7 shows that as $1/\gamma$ increases, the correlation between the trade balance and the terms of trade increases. To understand this behavior, note that from equations (2) and (9), and the budget constraint in (10), it follows that the trade balance, tb , in the model can be expressed as:

$$tb_t = e_t^p p_t^x e_t^y X - \frac{f_t}{(1-\alpha)}. \quad (18)$$

Thus, given the disturbances, the endowment of exportables, and the expenditure share $1-\alpha$, all of which are unchanged in the simulations summarized in Table 7, the behavior of the trade balance is determined by the behavior of imports. Therefore, the impact that changes in $1/\gamma$ have on the co-movement between the trade balance and the terms of trade is determined by the effects of changes in $1/\gamma$ on the equilibrium dynamics of imports, which are governed by equation (3). As the intertemporal elasticity of substitution rises, the contemporaneous correlation between the terms of trade and imports falls, reflecting the higher degree of substitutability between current and future imports--the correlation falls from 0.69 with $1/\gamma=0.2$ to -0.10 with $1/\gamma=1$. In other words, a rise in $1/\gamma$ constitutes a decline in the degree of relative risk aversion that induces individuals to distribute the impact of an improvement in the terms of trade at date t more evenly across consumption in all periods, hence lowering the correlation between the terms of trade and the trade balance. The increase in σ_{tb} that follows the increase in the degree of intertemporal consumption substitution is also consistent with this view. Lower risk aversion leads agents to adjust their savings more so as to accommodate a smoother

Table 7. Effects of Changes in the Intertemporal Elasticity of Substitution on the Behavior of the Balance of Trade 1/

$1/\gamma$	σ_{tb}	$\rho(1)$	$\rho_{tb, tot}$	$\rho_{tb, ym}$	$\rho_{tb, ydp}$
0.2	3.91	0.603	0.535	0.392	0.673
0.3	3.89	0.581	0.666	0.470	0.576
0.5	4.07	0.562	0.778	0.502	0.434
0.6	4.28	0.555	0.818	0.494	0.353
0.67 <u>2/</u>	4.41	0.549	0.836	0.484	0.307
0.8	4.72	0.542	0.860	0.452	0.223
1.0	5.21	0.534	0.876	0.391	0.126

1/ $1/\gamma$ is the intertemporal elasticity of substitution in consumption, the statistical moments are as in Table 6.

2/ Value in the benchmark simulation.

Table 8. Effects of Changes in the Intratemporal Elasticity of Substitution in the Behavior of the Balance of Trade 1/

$1/(1+\mu)$	σ_{tb}	$\rho(1)$	$\rho_{tb,tot}$	$\rho_{tb,ym}$	$\rho_{tb,ydp}$
0.2	2.35	0.634	0.757	0.651	0.278
0.3	3.16	0.597	0.795	0.624	0.300
0.5	3.67	0.571	0.815	0.575	0.318
0.6	3.99	0.563	0.823	0.539	0.313
0.74 <u>2/</u>	4.41	0.549	0.836	0.484	0.307
0.8	4.64	0.544	0.842	0.450	0.298

1/ $1/(1+\mu)$ is the intratemporal elasticity of substitution in consumption of tradable and nontradable goods, the statistical moments are as in Table 6.

2/ Value in the benchmark simulation.

consumption stream (the variability of consumption relative to the terms of trade falls from 0.73 to 0.67 as $1/\gamma$ changes from 0.2 to 1).

Table 7 also shows that the first-order serial autocorrelation of the trade balance falls slightly as $1/\gamma$ rises, and that while the co-movement between the trade balance and output at domestic prices falls, the co-movement between tb and output at import prices first increases and then falls to remain approximately unchanged. The small changes in the autocorrelation coefficient are to be expected, since the trade balance tends to reflect the same persistence common to the three random disturbances driving the model, $\theta=0.5$. The pattern of changes in the two measures of correlation with output are more difficult to interpret, particularly the fact that one changes monotonically with $1/\gamma$ and the other does not. This discrepancy may be due to the fact that the measure that considers output at import prices takes into account the stochastic processes driving the equilibrium relative price of non-tradables and the terms of trade.

As Table 8 indicates, an increase in the intratemporal elasticity of substitution between tradables and nontradables leads to an increase in the correlation between the trade balance and the terms of trade. As before, the rise in the co-movement between tb and the terms of trade reflects a fall in the correlation between the terms of trade and imports. However, in this case the weakening in this correlation is due to the fact that the rise in $1/(1+\mu)$ produces a decline in the co-movement between the terms of trade and the equilibrium relative price of nontradables--as $1/(1+\mu)$ goes from 0.2 to 0.8 this correlation falls from 0.73 to 0.41. In a model where nontradable goods are available in fixed supply, imports react less strongly to an increase in the terms of trade when the increase in the price of nontradable goods, resulting from the impact of wealth and substitution effects on the demand for nontradables, is smaller. The role of the increase in the price of nontradables, as Greenwood (1984) noted, is to induce agents to re-direct their desire to increase consumption of nontradables to increase their consumption of imports. The magnitude of the response in the price of nontradables, which is approximated here by its correlation with the terms of trade, reflects the magnitude of the demand pressure in the market of nontradables that is transferred to the imports market. The standard deviation of the trade balance also increases with $1/(1+\mu)$ because, given the unlimited supply of imports, consumption smoothing is more effective when the consumer views tradables and nontradables as close substitutes--the variability of consumption relative to the variability of the terms of trade falls from 1.20 to 0.58 as $1/(1+\mu)$ goes from 0.2 to 0.8.

As in Table 7, Table 8 shows that the persistence of the trade balance declines slightly as the elasticity of substitution between nontradables and tradables increases, but remains close to the first-order autocorrelation of the shocks. The behavior of the output-correlations, however, is now reversed. The correlation of tb with output at import prices falls from 0.65 to 0.45, while the correlation of tb with output at domestic prices

first increases slightly, and then falls to about the same level where it started. As before, it is likely that this behavior reflects mainly the impact of changes in μ on the stochastic process of the equilibrium price of nontradables, but it is not clear why one correlation declines monotonically while the other seems to reach a maximum when $1/(1+\mu)$ is around 0.5.

The effects of changes in the preference parameters μ and γ on the equilibrium stochastic processes of the model with incomplete markets differ significantly from the effects that are observed in complete-markets models. Contrary to what Tables 7 and 8 show, Backus (1989) proved analytically that in a model of a barter economy with complete markets, the terms of trade tend to exhibit stronger positive correlation with the trade balance the lower are the inter and intratemporal elasticities of substitution. In support of this result, an experiment in which $1/(1+\mu)$ is increased from 0.44 to 0.74 in Stockman and Tesar (1991) produces a decline in the correlation between the terms of trade and the trade balance from 0.4 to 0.18, while in Backus, Kehoe, and Kydland (1991b) the co-movement between tb and the terms of trade falls from 0.76 to -0.28 as the elasticity of substitution between foreign and domestic goods is increased from 0.5 to 4. ^{1/}

These conflicting results illustrate that the emphasis that models of incomplete markets give to country-specific income shocks is reflected not only on predictions regarding the role of the persistence of those shocks, but also on implications for how changes in preference parameters affect equilibrium co-movements. Specifically, under incomplete markets the strength of wealth effects is such that an increase in the elasticity of substitution between tradable and nontradable goods leads to an increase in the correlation between the trade balance and the terms of trade, while in models of complete markets substitution effects seem to dominate and the result is the opposite.

Given the results of the sensitivity analysis, it is natural to question whether cross-country differences in the parameters θ , γ , and μ could account for the differences observed in the actual stylized facts. In two important instances the answer would be negative. First, for most of the values of the three parameters that were considered, the two output-correlation measures still exaggerate the actual GDP correlations. Thus, the inability of the model to account for the countercyclical fluctuations of the trade balance cannot be attributed to errors in the measurement of the persistence of income shocks or the parameters of the utility function. Second, with regard to the real exchange rate, the model cannot produce sufficient variability unless the elasticity of substitution between

^{1/} In Stockman and Tesar (1991) and Backus, Kehoe, and Kydland (1991b) the terms of trade are the inverse of the measure used in this paper. Thus, the correlations between the trade balance and the terms of trade that appear in their papers have the opposite signs from those referred to in the text.

tradable and nontradable goods is set to be quite low--with $1/(1+\mu)=0.2$, the standard deviation of the real exchange rate is 4.66 percent. In contrast, observed differences across countries in other stylized facts could be explained on the basis of differences in parameter values. Slight changes in θ , γ , and μ could account for differences in the magnitude of the Harberger-Laursen-Metzler effect, except in the cases of Canada and the United States where the correlation between the trade balance and the terms of trade is negative. These changes could also account for differences in the variability and persistence of the balance of trade, and in the behavior of aggregate consumption and its tradable and nontradable components.

VII. Concluding Remarks

This paper examined numerically the equilibrium stochastic processes that characterize the dynamics of an intertemporal optimizing model of a small open, barter economy where insurance markets are incomplete. Agents consume three goods, two of which are tradable, a home good and an imported good, and one of which is nontradable. Stochastic disturbances affect endowments, the terms of trade, and the real interest rate.

A benchmark model was parameterized using as guides the actual stylized facts for output, term-of-trade, and interest-rate fluctuations, and other empirical regularities, as well as existing empirical evidence on preference parameters. The model was simulated and the resulting unique invariant joint limiting distribution of the disturbances and the holdings of foreign financial assets was used to compute moments of variability, co-movement, and persistence of the endogenous variables. The model mimics some of the observed stylized facts, particularly the Harberger-Laursen-Metzler effect and the cyclical properties of aggregate consumption, but it cannot explain other important empirical regularities. The assumption of a barter economy where investment decisions are ignored prevents the model from re-creating the countercyclical behavior of the balance of trade, and results in excessive variability in net factor payments abroad and holdings of foreign assets. The model also underestimates significantly the income elasticity of imports and the variability of the real exchange rate.

Additional simulations were performed to analyze the sensitivity of the model's equilibrium co-movements to changes in the persistence of income disturbances and changes in preference parameters. This analysis showed that, given incomplete insurance markets, the predictions from the theoretical literature on dynamic equilibrium models for small open, barter economies, which emphasized the role of the persistence of income shocks, extend to the equilibrium paths of a model with uncertainty. Preference parameters also affect the equilibrium co-movements, but given the importance of income effects under incomplete markets, they seem to do so in the opposite direction from what models with complete markets predict.

The results of this investigation suggest that the analysis of a real business cycle model of a small open economy with traded and nontraded goods

would be a useful development. The integration of investment would overcome the inability of the endowment's model to produce a countercyclical trade balance, as the analysis of one-good models has shown, and it would also produce realistic consumption-output correlations that are not present in the model with one good. Such a model could explore the role of terms-of-trade shocks as a driving force of business cycles, and would also serve to assess the macroeconomic effects of trade liberalization and other commercial policies.

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