1 The International Effects of Monetary and Fiscal Policy in a Two-Country Model

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Introduction

In Mundell 1968 (chap. 18), Robert Mundell develops a model of the international transmission effects of monetary and fiscal policy shocks in a two-country version of what is now known as the Mundell-Fleming model. Mundell shows that under floating exchange rates, positive monetary policy innovations tend to have a "beggar-thy-neighbor" effect, raising domestic output but, through the effects of real depreciation, lowering foreign output. On the other hand, fiscal policy shocks tend to increase output in both countries.

The intuition behind the Mundell model remains at the center of a vast literature on the international policy transmission mechanism that has developed in the decades since floating exchange rates became a reality. It formed the background for the celebrated Dornbusch (1976) model. Extended versions of the model were used heavily in the mid-1980s to study the problems of international macroeconomic policy coordination (e.g., McKibbin and Sachs 1986). More recently, Taylor (1993) used a further extended Mundell-type model in an empirical analysis of international monetary policy in a multicountry environment.

Although the Mundell-Fleming model has remained highly influential in both academic and policy circles, developments in macroeconomics beginning in the late 1970s questioned the use of models in which the underlying preferences and technology were not fully specified and long-run budget constraints were not satisfied. The reworking of macroeconomic models to encompass dynamic economic theory is now at an advanced stage. But only recently have open-economy macroeconomists reached the stage where they can readdress Mundell's questions within a more modern framework. An important

paper in this regard is that of Obstfeld and Rogoff (1995)[1] (henceforth OR). They argue that to understand short-run macroeconomics in the open economy, it is important to move beyond the Mundell-Fleming model toward a dynamic, utility-maximizing framework, where long-run budget constraints are satisfied.

This chapter develops the OR agenda in the direction of readdressing the issues analyzed in Mundell 1968. We set up a two-country, dynamic general equilibrium model in which prices adjust only slowly and investigate the main characteristics of the international macroeconomic transmission mechanism within this framework. We explore two important dimensions of the model: (a) the currency of export price invoicing, and (b) the degree of completeness of assets markets. In particular, we develop a framework in which export prices may be set in terms of the foreign currency (which we call "pricing-to-market"), rather than in domestic currency, as assumed by Mundell 1968 and OR. Since prices are sticky, this produces deviations from the law of one price (LOOP), which is consistent with the strong recent evidence of deviations from LOOP in traded goods (e.g., Engel and Rogers 1996). The model's second key feature is that we allow the structure of international asset markets to vary between an environment of complete markets, in which there is perfect cross-country coinsurance, and a more limited asset markets environment, in which noncontingent bonds are the only asset that may be traded across countries.

We first set out some stylized facts concerning the monetary policy transmission mechanism using G-7 data. We show that empirically, positive U.S. monetary policy shocks tend to raise output in both the United States and other G-7 countries. That is, monetary policy has positive international transmission effects on output. In addition, we show that a positive U.S. monetary policy disturbance causes a persistent real exchange rate depreciation and a persistent fall in U.S. short-term interest rates relative to G-7 interest rates.

We may summarize our results in two parts. First, the theoretical analysis of the policy transmission mechanism reveals a sharp dichotomy between the importance of the invoicing currency (or pricing-to-market) and the importance of asset market incompleteness. We find that for the analysis of the international monetary transmission mechanism, the structure of assets markets has very little importance. The monetary transmission mechanism differs only slightly between the complete markets environment and the incomplete markets environment. On the other hand, the degree of pricing-to-market is critical to the monetary transmission mechanism. The effects

of monetary policy on output, consumption, the real exchange rate, and the terms of trade are all reversed when we move from a situation of domestic currency export price invoicing to a situation of pricing-to-market.

In the analysis of fiscal policy, we find by contrast that the degree of pricing-to-market is of very little consequence. The international transmission effects of fiscal spending are not sensitive to the currency of export price invoicing. All major aggregates move both qualitatively and quantitatively in the same way under either pricing regime in response to fiscal spending shocks. However, the structure of international asset markets is critical to the analysis of the transmission of fiscal spending. We find that with complete international asset markets, fiscal spending shocks have no real or nominal exchange rate effects and no terms-of-trade effects at all. Moreover, with complete asset markets, fiscal spending shocks have an identical impact on consumption and output for all countries. But with limited international asset markets, a domestic fiscal spending expansion will cause a terms-of-trade deterioration and a real and nominal exchange rate depreciation and also cause domestic and foreign consumption and output to move in opposite directions. Thus the degree of international insurance available in assets markets is of central importance to the effects of fiscal policy transmission.

The second aspect of our results concerns the match between our empirical results on the international monetary transmission mechanism and the findings of our theoretical model. We argue that the version of the model with pricing-to-market does a good job of matching the basic stylized facts of the international monetary policy transmission mechanism as documented by vector auto-regression (VAR) results. With pricing-to-market, monetary policy shocks tend to produce a positive comovement of output across countries, a persistent real exchange rate depreciation, and a decrease in the international interest rate differential.

The chapter is organized as follows. The next section gives our empirical results, and the following section develops the basic model. Subsequent sections discuss calibration, report the quantitative results of the model, and offer some conclusions.

Empirical Evidence

The chapter's goal is to establish both empirical evidence and a theoretical model concerning the international transmission of

macroeconomic policy. In this section, we present some empirical evidence regarding the effects of monetary policy shocks on output levels, real exchange rates, and interest rates.[2]

We use monthly, seasonally adjusted data from the IMF's International Financial Statistics database for the G-7 countries on industrial production, interest rates, aggregate (CPI) price indices, and bilateral nominal exchange rates with the United States. Using the data for six countries—Canada, France, Germany, Italy, Japan, and the United Kingdom—we then construct a simple G-7 aggregate industrial production index, an average price level, an average short-term, market-based nominal interest rate, and an average nominal bilateral exchange rate with the United States. We also employ U.S. data for each of the first four of these variables and two measures of U.S. monetary policy instruments: nonborrowed reserves of the Federal Reserve system and the federal funds rate. Using the aggregate foreign price index, the U.S. price index, and the average nominal exchange rate of the G-7 aggregate, we construct a multilateral "real exchange rate" between the G-7 aggregate and the United States.

We construct and estimate two vector auto-regressions for the purpose of examining the conditional correlation between two measures of orthogonal shocks to U.S. monetary policy and the interest rates of both the United States and the G-7 aggregate, the real exchange rate between the United States and the G-7 aggregate, and the output levels of the United States and the G-7 aggregate.

We employ a perfectly standard methodology for estimating and identifying the VARs in which the innovation to each variable is orthogonalized, and we omit a full description of it here.[3] The basic idea is that we estimate a reduced-form VAR, then identify the Choleski decomposition of this VAR, in which all shocks (including the monetary policy shock) are orthogonalized and in which the monetary shock is ordered first in the empirical model. In other words, we identify an empirical model in which orthogonal shocks to U.S. monetary policy instruments may be construed as exogenous policy innovations, in the sense that the Fed sets values for these shocks independent of current information on outputs, interest rates, and the real exchange rate between the United States and the G-7 aggregate but conditional on all information on lagged values of these variables.

The two VARs that we estimate are specified as follows. The first is specified in the following vector of endogenous variables, which are ordered as indicated in the vector $\mathbf{X} = [NBR, I - I^*, Y, Y^*, RER]'$. Here,

NBR denotes nonborrowed reserves of the U.S. Federal Reserve, I and I^* denote the U.S. and G-7 aggregate short-term net nominal interest rates, Y and Y^* are U.S. and G-7 aggregate industrial production indices, and $RER = EP^*/P$ denotes the real exchange rate of the United States with respect to the G-7 aggregate. In particular, E is the U.S. dollar price of a unit of G-7 aggregate currency, P and P^* are the U.S. and G-7 aggregate consumer price indices respectively, and RER is therefore the U.S. consumption goods price of a G-7 aggregate consumption good. All variables are in natural logarithms, except the nominal interest rate differential, which is a level. The second VAR is specified in the vector of endogenous variables $\mathbf{X} = [FF, I^*, Y, Y^*, RER]'$. Here, FF denotes the Federal Funds Rate and I^* denotes the G-7 aggregate short-term, market-based net nominal interest rate.

In addition, all variables are Hodrick-Prescott filtered, and both VARs are estimated with an optimized (by standard criteria) lag length of four. In choosing to H-P filter the data, we are assuming that each of the variables in the VAR is likely to be characterized by a stochastic trend component. Obviously, there are many potential pitfalls in applying the H-P filter, especially if the variables are actually stationary. For example, Cogley and Nason (1995) present results indicating that the H-P filter induces correlation and business cycle dynamics even if none are present in the original data. Equally, however, there are many pitfalls involved in actually testing for stochastic nonstationarity and assuming a VAR specification based on, for example, first-differencing the data and possibly incorporating error correction terms to account for estimated cointegrating vectors between the relevant series. These pitfalls are largely associated with the power properties of such tests.

We choose to employ the H-P filter so as to maintain consistency with data typically used to evaluate business cycle models. We feel that it is unlikely that our variables are cointegrated (for example, because of the presence of productivity trends in the output or real exchange rate series). Estimating the same VARs using first-differenced data did not change the results qualitatively, although the impulse response functions, which map out the dynamic effects for each of the endogenous variables of money shocks, exhibited greater variability.

Figures 1.1a–1.1d and figures 1.2a–1.2d illustrate the results that we obtain for the first and second VAR specifications, respectively. These are the impulse response functions for the real exchange rate, the relevant interest rate variable, and industrial outputs to a one-standard-deviation expansionary innovation to the relevant monetary policy

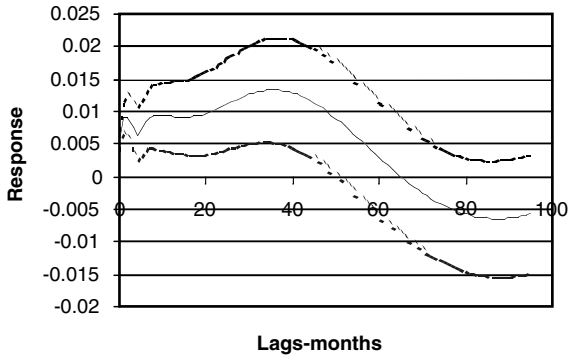

Figure 1.1a
EP/P* response to U.S. money shock

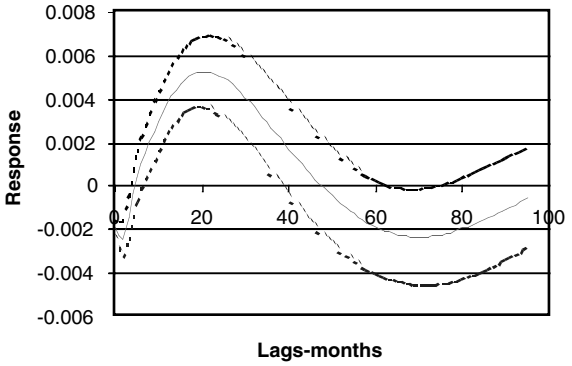

Figure 1.1b
Y response to U.S. money shock

instrument. Clearly the qualitative and even the quantitative features of the responses of interest rates, industrial output levels, and the real exchange rate are virtually identical across the two specifications. First, a large, persistent, and significant real exchange rate depreciation is associated with either monetary impulse (a one-standard-deviation positive innovation to NBR and a one-standard-deviation negative innovation to the federal funds rate). Second, a positive innovation to *NBR* has a large and significant "liquidity effect" on the nominal interest differential, whereas a negative innovation to the federal funds rate has a large and significant liquidity effect on the G-7 aggregate interest rate. Third, U.S. output first experiences a very small and barely

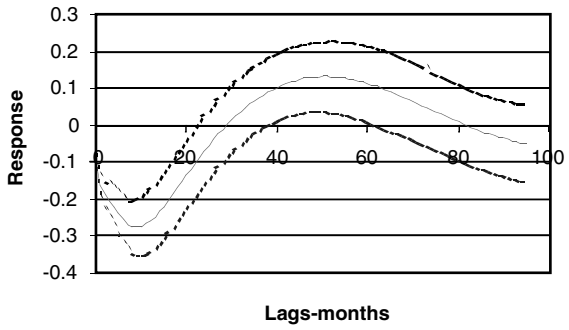

Figure 1.1c
$I - I^*$ response to U.S. money shock

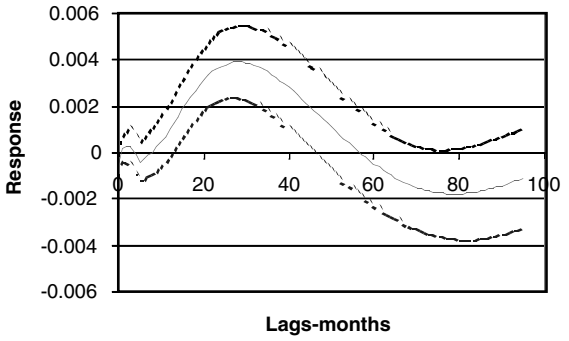

Figure 1.1d
Y^* response to U.S. money shock

significant initial decline that is immediately reversed, and becomes a positive and highly significant increase.[4] Finally, it is evident that in either specification of monetary policy shocks, the foreign output response, although delayed for a period of six to eight months, is ultimately positive and significant.

We found these responses to be robust to several changes in ordering of the endogenous variables and to alternative specifications of the model. In particular, we found that when we estimated the same VARs separately for each G-7 country in relation to the United States, we obtained results qualitatively identical to those that we report here.[5]

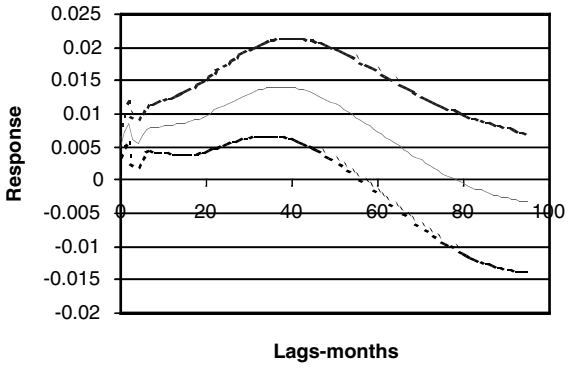

Figure 1.2a
EP/P* response to U.S. money shock

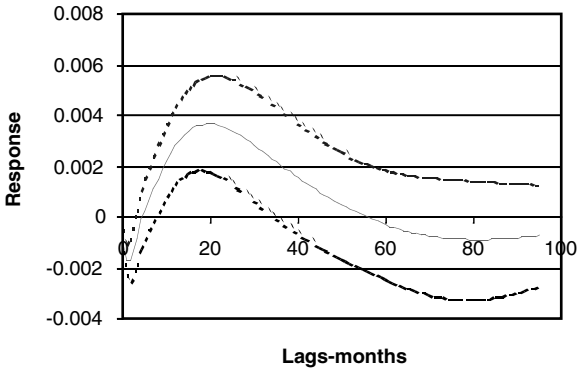

Figure 1.2b
Y response to U.S. money shock

Based on earlier empirical work of our own (Betts and Devereux 1996, 1998) as well as that of others (Eichenbaum and Evans 1995 and Schlagenhauf and Wrase 1995) and the additional results that we have reported here, we regard the positive output responses, real exchange rate depreciation, and liquidity effects for interest rates following monetary policy innovations as stylized facts to be accounted for by any good model of the international monetary policy transmission mechanism. We now develop a model that, among other things, can account for the positive output transmission of monetary policy shocks.

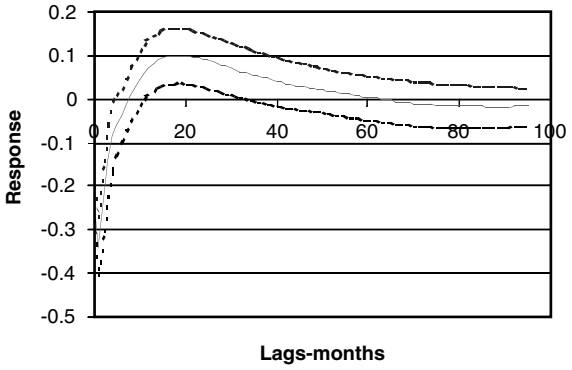

Figure 1.2c
$I - I^*$ response to U.S. money shock

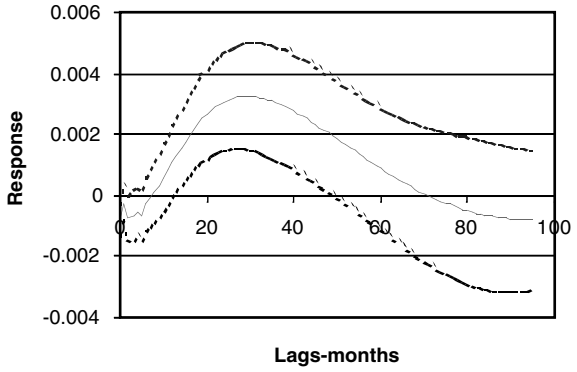

Figure 1.2d
Y^* response to U.S. money shock

A Two-Country Model of the Policy Transmission Mechanism

Modern approaches to the analysis of international macroeconomic policy transmission rely heavily on formal modeling of the type developed in OR. In this section we develop a model that can be used to explore the questions posed by Mundell, except that it is based explicitly on formal utility and profit maximization in an intertemporal setting, and the imposition of intertemporal budget constraints on all agents.

The model has two countries, which we denote "home" and "foreign." Within each country exist consumers, firms, and a govern-

ment. Government spends directly on goods and services and issues fiat money. To keep the analysis simple, we will not formally distinguish between the central bank and the fiscal authority.

We assume that there is continuum of goods varieties in the world economy of measure 1 and that the relative size of the home and foreign economy's share of these goods is n and $(1-n)$, respectively. We choose units so that the populations of the home and foreign country are also n and $(1-n)$, respectively. In addition, in each country, a fraction s of goods varieties are invoiced in the currency of the buyer, and the remaining $(1-s)$ goods varieties are priced in the currency of the seller. As we describe in greater detail below, firms that produce s goods varieties are also assumed to be able to segment markets, country by country, whereas firms that produce $(1-s)$ goods varieties cannot. Thus it is possible for the prices of s goods in the home and foreign market to exhibit deviations from LOOP, whereas the prices of $(1-s)$ goods must always satisfy LOOP.

Let the state of the world be defined as z_t. In each period t, there is a finite set of possible states of the world. Let z^t denote the history of realized states between time 0 and t, that is, $z^t = \{z_0, z_1, \ldots, z_t\}$. The probability of any history, z_t, is denoted by $\pi(z^t)$.

Typically, we will write the features of the model for the home country economy alone. The conditions for the foreign country are analogously defined in all cases, except those that are explicitly derived.

Consumers

We assume that preferences are identical across countries. In the home country, consumers have preferences given by

$$EU = \sum_{t=0}^{\infty} \sum_{z^t} \beta^t \pi(z^t) U\left(C(z^t), \frac{M(z^t)}{P(z^t)}, (1-h(z^t)) \right), \tag{1.1}$$

where

$$C(z^t) = \left(\int_0^1 c(i, z^t)^{1-1/p} di \right)^{\rho/(\rho-1)},$$

and

$$c(i, z^t) = \left(\sum_0^N x(i, j, z^t)^{1-1/\lambda} \right)^{\lambda/(\lambda-1)}.$$

In addition, we assume the specific functional form given by

$$U\left(C, \frac{M}{P}, 1-h\right) = \frac{C^{1-\sigma}}{1-\sigma} + \frac{\varsigma}{1-\varepsilon}\left(\frac{M}{P}\right)^{1-\varepsilon} + \eta \ln(1-h).$$

The consumer derives utility from a composite consumption good $C(z^t)$, real home-country money balances $M(z^t)/P(z^t)$, and leisure, where $h(z^t)$ represents hours worked. The composite consumption good is an aggregate of a continuum of differentiated varieties, where $c(i, z^t)$ represents the consumption of variety i. Within each variety, there is a further disaggregation into N types, so that $x(i, j, z^t)$ represents the consumption of variety i, type j good. We introduce types of good within each variety in order to allow for a distinction between two key parameters in the model: the elasticity of substitution between home and foreign goods and the parameter governing price markups over marginal costs.

Households also value real home-currency money balances, where the home CPI is defined as

$$P(z^t) = \left[\int_0^n p(i, z^t)^{1-\rho}\, di + \int_n^{n+(1-n)s} p^*(i, z^t)^{1-\rho}\, di \right.$$
$$\left. + \int_{n+(1-n)s}^1 \left(e(z^t) q^*(i, z^t)\right)^{1-\rho} di\right]^{1/(1-\rho)}.$$

The CPI depends on the price of n home goods and $1 - n$ foreign goods. Of these foreign goods, s goods are priced in domestic currency and have prices denoted $p^*(i, z^t)$, and $1 - s$ goods are priced in foreign currency and satisfy LOOP, so that the home-country price must be $e(z^t)q^*(i, z^t)$, where $e(z^t)$ is the exchange rate (price of foreign currency), and $q^*(i, z^t)$ is the foreign-country price of variety i. Within each variety, there is a further subprice index defined as

$$p(i, z^t) = \left[\sum_0^N p(i, j, z^t)^{1-\lambda}\right]^{1/(1-\lambda)}.$$

The representative consumer in the home country receives income in wages from employment, rents from holdings of physical capital, profits from the ownership of domestic firms, and income from asset holdings and existing money balances, and accepts transfers and/or pays taxes to the domestic government. Households then consume, accumulate capital and money balances, and purchase new assets.

We explore the consequences of two asset market structures. In the first type, there exist full and complete state-contingent asset markets. Agents can buy nominal state-contingent bonds. The home-country budget constraints are then written as

$$P(z^t)C(z^t) + M(z^t) + \sum_{z^{t+1}} w(z^{t+1}, z^t)b(z^{t+1}) + P(z^t)V(z^t) \\ = W(z^t)h(z^t) + R(z^t)K(z^t) + \Pi(z^t) + M(z^{t-1}) + b(z^t) + TR(z^t), \tag{1.2}$$

where

$$K(z^t) = \phi\left(\frac{V(z^{t-1})}{K(z^{t-1})}\right)K(z^{t-1}) + (1-\delta)K(z^{t-1}). \tag{1.3}$$

The home consumer purchases a portfolio of state-contingent home-currency-denominated nominal bonds at price $w(z^{t+1}, z^t)$. In addition, she purchases a composite investment good $V(z^t)$, which requires the same basket of goods as the consumption index and forms next period's capital holdings. Since the investment good is constructed in the same way that the composite consumption good is, they have the identical composite price $P(z^t)$. The consumer also receives net transfers $TR(z^t)$ from the government and nominal, domestic currency profits from all domestic firms, which are denoted by $\Pi(z^t)$. In addition, $R(z^t)$ denotes the nominal rental return on a unit of capital, and δ denotes the depreciation rate of capital.

Investment is used to accumulate household capital according to equation (1.3). Accumulating capital is subject to adjustment costs. An increase in investment of one unit raises the next-period capital by $\phi'(.) < 1$ units. The function $\phi(.)$ must satisfy the conditions $\phi'(.) > 0$ and $\phi''(.) < 0$.

In the second type of asset market structure, following OR, we assume that the only assets that can be traded are non-state-contingent one-period home-currency-denominated nominal bonds. In this economy, the home consumer's budget constraint is written as

$$P(z^t)C(z^t) + M(z^t) + w(z^t)B(z^t) + P(z^t)V(z^t) = \\ W(z^t)h(z^t) + R(z^t)K(z^t) + \Pi(z^t) + M(z^{t-1}) + B(z^{t-1}) + TR(z^t), \tag{1.4}$$

again subject to equation (1.3), where $w(z^t)$ is the time t nominal bond price. The key difference between (1.3) and (1.4) is that in the latter, the consumer can smooth out the effects of income fluctuations only over time and not across states of the world.

The consumer's optimal consumption, money holdings, investment, and labor supply may be described by the following familiar conditions. First, in the complete markets environment we have the following conditions

$$w(z^{t+1}, z^t)C(z^t)^{-\sigma} = \beta\pi(z^{t+1})\frac{P(z^t)}{P(z^{t+1})}C(z^{t+1})^{-\sigma}, \tag{1.5}$$

$$\frac{M(z^t)}{P(z^t)} = \left[\varsigma C(z^t)^{\sigma}\frac{1+i(z^t)}{i(z^t)}\right]^{1/\varepsilon}, \tag{1.6}$$

$$\frac{\eta}{1-h(z^t)} = \frac{W(z^t)}{P(z^t)C(z^t)^{\sigma}}, \tag{1.7}$$

$$\frac{C(z^t)^{-\sigma}}{\phi'\left(\frac{V(z^t)}{K(z^t)}\right)} = \beta\sum\nolimits_{z^{t+1}}\pi(z^{t+1})C(z^{t+1})^{-\sigma}\left[\frac{R(z^{t+1})}{P(z^{t+1})} + J(z^{t+1}, z^t)\right], \tag{1.8}$$

where

$$J(z^{t+1}, z^t) = \frac{1}{\phi'\left(\frac{V(z^{t+1})}{K(z^{t+1})}\right)}\left[\phi\left(\frac{V(z^{t+1})}{K(z^{t+1})}\right) - \phi'\left(\frac{V(z^{t+1})}{K(z^{t+1})}\right)\frac{V(z^{t+1})}{K(z^{t+1})} + (1-\delta)\right].$$

Equation (1.5) describes the state-contingent choice of intertemporal consumption smoothing, and (1.6) gives the consumer's implied demand for money. The term $i(z^t)$ represents the nominal interest rate, where

$$\frac{1}{1+i(z^t)} = \sum\nolimits_{z^{t+1}} w(z^{t+1}, z^t).$$

Equation (1.7) describes the labor supply choice, and (1.8) results from the optimal choice of investment in the presence of adjustment costs.

In the incomplete markets environment, equations (1.6), (1.7), and (1.8) continue to hold, where in (1.6), the nominal discount factor is now defined as

$$\frac{1}{1+i(z^t)} = w(z^t).$$

Equation (1.5) is replaced by

$$w(z^t)C(z^t)^{-\sigma} = \beta\sum\nolimits_{z^{t+1}}\frac{P(z^t)}{P(z^{t+1})}C(z^{t+1})^{-\sigma}. \tag{1.9}$$

Cross-Country Consumption Insurance

The different asset market structures principally affect the possibilities for cross-country consumption insurance. In the complete

markets environment, it is easy to establish that optimal risk sharing will imply

$$\frac{C(z^t)}{C^*(z^t)} = \Lambda\left(\frac{Q(z^t)e(z^t)}{P(z^t)}\right)^{1/\sigma}, \tag{1.10}$$

where Λ is a constant reflecting initial wealth differences. This says that if purchasing power parity (PPP) holds, then consumption levels are equated up to the constant Λ as agents confront identical commodity prices. Here Q represents the foreign price. Movements in the real exchange rate or departures from PPP, however, will be reflected in different consumption rates. Despite the presence of complete insurance markets, it is not efficient to fully equalize consumption rates across countries unless PPP holds. As we see below, the presence of pricing-to-market will lead to persistent deviations from PPP.

In the bond market economy, on the other hand, there is no possibility for state-contingent consumption insurance. However, the (home-currency) nominal interest rate facing domestic and foreign agents is equal. Thus, we have

$$\begin{aligned} w(z^t) &= \beta\sum\nolimits_{z^{t+1}} \pi(z^{t+1})\frac{P(z^t)}{P(z^{t+1})}\frac{C(z^{t+1})^{-\sigma}}{C(z^t)^{-\sigma}} \\ &= \beta\sum\nolimits_{z^{t+1}} \pi(z^{t+1})\frac{Q(z^t)}{Q(z^{t+1})}\frac{e(z^t)}{e(z^{t+1})}\frac{C^*(z^{t+1})^{-\sigma}}{C^*(z^t)^{-\sigma}}. \end{aligned} \tag{1.11}$$

Whereas in the complete markets economy, deviations from PPP determine cross-country differences in the levels of consumption, in the bond market economy they drive a wedge between home- and foreign-country consumption growth rates. This is the critical difference between the two asset market structures.

Government

Governments in each country print money, levy taxes and purchase goods to produce a composite government consumption good. To economize on notation, we assume the government does not issue bonds and so must always balance its within-period budget. It is assumed that the government composite good is produced using the same aggregator that private consumption and investment goods use. The home-country government budget constraint is then

$$M(z^t) - M(z^{t-1}) = P(z^t)G(z^t) + TR(z^t), \tag{1.12}$$

where $G(z^t)$ represents the government composite good. We assume that the share of government spending in GDP is set by policy at rate θ_t.

Firms

Firms in each country hire capital and labor to produce output. Each type of good of each variety has a separate, price-setting firm. The number of firms within each variety, N, is sufficiently large that each firm ignores the impact of its pricing decision on the aggregate price index for that variety. A firm of variety i, type j, has production function given by

$$y(i, j, z^t) = k(i, j, z^t)^{\alpha} \ell(i, j, z^t)^{1-\alpha} - v, \tag{1.13}$$

where $k(i, j, z^t)$ is capital usage and $\ell(i, j, z^t)$ is labor usage. Firms must also bear a fixed cost of production v.

All firms will choose factor bundles to minimize costs. Thus, we must have

$$W(z^t) = MC(z^t)(1-\alpha)\frac{y(i, j, z^t)}{\ell(i, j, z^t)}, \tag{1.14}$$

$$R(z^t) = MC(z^t)\alpha\frac{y(i, j, z^t)}{k(i, j, z^t)}, \tag{1.15}$$

where $MC(z^t)$ is nominal marginal cost, which must be equal for all firms within the home economy. From (1.13), (1.14), and (1.15), it is clear that all firms in the home economy will have the same capital-labor ratio.

Pricing

We assume that firms must set nominal prices in advance. There are two features to the price-setting mechanism. The first concerns the currency of pricing. As we noted above, a subset s of firms set prices in the buyer's currency. Thus a home firm in this category will set a price p for sale to home consumers but a price q, denominated in foreign currency, for sale to foreign consumers. An unanticipated change in the exchange rate will cause a deviation from LOOP, which would require that $p = eq$. To avoid the arbitrage opportunity that this deviation implies, the firm must be able to segment its home and foreign markets.

We denote this type of pricing behavior as pricing-to-market (PTM). The remaining $(1 - s)$ of firms are unable to segment their markets by country and must set a unified price. In this case, we assume they price in their home currency. Thus a home firm in this category will set its price p, the same price charged to both home and foreign consumers.

The second feature of price setting is the way in which prices adjust. Following Calvo (1983), Yun (1996), and Kimball (1996), we assume that firms change their prices at random intervals dictated by a Poisson arrival rate. Each sector changes its price with probability $(1 - \gamma)$ in any period. Thus the average time between price changes for any one firm is $1/(1 - \gamma)$. Then, by the law of large numbers, exactly $(1 - \gamma)$ times the number of sectors (and therefore firms) in the economy will be changing their price in any given period.

The exact price-setting problem that the firm faces will depend on the degree of market completeness. Take first the case of complete markets. Given preferences as stated above, the firm will at any period face a price elasticity of demand equal to λ. Since its current price choice will affect its future expected profits, the firm will face the problem of choosing prices to maximize state-contingent profits. Take the case of a PTM firm in the home economy. Its state-contingent profits, in present value, may be written as

$$\begin{aligned}&\sum_{t=0}^{\infty}\sum_{z^t}\varphi(z^t)\gamma^t\Big[p(i,j,z^t)x_d(i,j,z^t)+e(z^t)q(i,j,z^t)x_d^*(i,j,z^t)\\&\quad -MC(z^t)\big(x_d(i,j,z^t)+x_d^*(i,j,z^t)\big)\Big],\end{aligned} \tag{1.16}$$

where

$$\varphi(z^t)=\prod_{j=1}^{t}w(z^j,z^{j-1}),$$

for $t = 1, 2, \ldots,$ is the period 0 price of a delivery of \$1 in state z^t, with $\varphi(z^0) = 1$, and $x_d(i, j, z^t)$ is the demand schedule of firm i, j by home consumers, etc.

With incomplete markets, the appropriate objective function for the firm is less clear. We will assume that the firm chooses prices so as to maximize the expected present value of profits, using the market nominal discount factors.[6] The firm's objective function in this case is then

$$E_0 \sum_{t=0}^{\infty} \Omega(z^t)\gamma^t \Big[p(i, j, z^t) x_d(i, j, z^t) + e(z^t) q(i, j, z^t) x_d^*(i, j, z^t) \\ - MC(z^t)\big(x_d(i, j, z^t) + x_d^*(i, j, z^t)\big)\Big] \tag{1.17}$$

where

$$\Omega(z^t) = \prod_{j=1}^{t} w(z^{j-1}),$$

for $t = 1, 2, \ldots$, with $\Omega(z^0) = 1$.

A PTM firm that is changing its price in a given period t will choose its prices for the domestic and foreign markets p and q, respectively, to maximize (1.16) or (1.17), depending upon the asset market structure. From the structure of the model described above it is clear that each firm will face a constant price elasticity of demand equal to λ. Now define as $\tilde{p}(i, j, z^t)$ the price set by firm j, in sector i, when it newly sets its price at time t, given the history z^t. Choosing $\tilde{p}(i, j, z^t)$ to maximize (1.16) gives the condition

$$\tilde{p}(i, j, z^t) = \Big(1 - \sum_{z^{t+1}} \omega(z^{t+1}, z^t)\Big) \frac{\lambda}{\lambda - 1} MC(z^t) \\ + \sum_{z^{t+1}} \omega(z^{t+1}, z^t) \tilde{p}(i, j, z^{t+1}), \tag{1.18}$$

where

$$\omega(z^{t+1}, z^t) = \frac{\gamma w(z^{t+1}, z^t) \sum_{k=t+1}^{\infty} \sum_{z^k} \varphi(z^k) \gamma^{k-t-1} x(i, j, z^k)}{\sum_{k=t}^{\infty} \sum_{z^k} \varphi(z^k) \gamma^{k-t} x(i, j, z^k)}.$$

That is, the optimal newly set price of the firm is a function of current and expected future marginal costs.

Likewise, the newly set price for the foreign market can be described by the condition

$$\tilde{q}(i, j, z^t) = \Big(1 - \sum_{z^{t+1}} \vartheta(z^{t+1}, z^t)\Big) \frac{\lambda}{\lambda - 1} \frac{MC(z^t)}{e(z^t)} \\ + \sum_{z^{t+1}} \vartheta(z^{t+1}, z^t) \tilde{q}(i, j, z^{t+1}), \tag{1.19}$$

where

$$\vartheta(z^{t+1}, z^t) = \frac{\gamma w(z^{t+1}, z^t) \sum_{k=t+1}^{\infty} \sum_{z^k} \varphi(z^k) \gamma^{k-t-1} x^*(i, j, z^k)}{\sum_{k=t}^{\infty} \sum_{z^k} \varphi(z^k) \gamma^{k-t} x^*(i, j, z^k)}.$$

Note that in comparing (1.18) and (1.19), we see that in a perfectly deterministic environment, the firm would always set its price so that $\tilde{p} = e\tilde{q}$, that is, LOOP would hold. This results from the fact that the elasticity of demand is constant and the same in the home and foreign market. Furthermore, this will be true of all goods as a result of the symmetry across firms. As a result, in a deterministic environment without monetary or fiscal policy shocks, PPP will hold. But in the presence of exchange rate uncertainty, the newly set prices will show systematic deviations from LOOP.

Although we have examined only the case of a PTM firm in the home economy, it is clear that a non-PTM firm's price will be described solely by a condition similar to (1.18).

In the incomplete asset markets case, the pricing decision will be described exactly as in (1.18) and (1.19), save for the fact that the weights ω and ϑ will differ by the different definition of the discount factor. Since all our results are derived by linear approximation, this makes no difference in what follows.

The structure of firms is entirely symmetric, so it is clear that all home firms, in any sector, will set the same value of $\tilde{p}$ and $\tilde{q}$. In addition, for any sector i, we have the price given by (slightly abusing notation) $p_t(i) = (1 - \gamma)\tilde{p} + \gamma p_{t-1}(i)$. Then defining the home-country price index for home-priced goods as

$$p(z^t)^{1-\rho} = \int_0^n p(i, z^t)^{1-\rho}\, di$$

and using the law of large numbers, we see that

$$p(z^t)^{1-\rho} = (1-\gamma)\tilde{p}(z^t)^{1-\rho} + \gamma p(z^{t-1})^{1-\rho}. \tag{1.20}$$

In a parallel manner, if we define the index of prices of foreign-currency-invoiced goods by home-country sectors as

$$q(z^t)^{1-\rho} = \int_{n(1-s)}^{ns} q(i, z^t)^{1-\rho}\, di,$$

we may show that

$$q(z^t)^{1-\rho} = (1-\gamma)\tilde{q}(z^t)^{1-\rho} + \gamma q(z^{t-1})^{1-\rho}. \tag{1.21}$$

Market Clearing

Within a country, all firms use the same capital-labor ratio. Therefore we may aggregate across firms and sectors to define the aggregate output in the home economy as

$$y = K^{\alpha}h^{1-\alpha} - vN.$$

Output must equal aggregate demand for the home country. Total demand comes from the following sources. First, there is demand for the consumption goods of the non-PTM firms, by both home and foreign consumers. Then there is the demand for the consumption goods of the PTM firms by home consumers and foreign consumers separately. Second, there is demand for investment goods of both non-PTM and PTM firms. Finally, there is the demand by government for the output of all firms. The market-clearing equation for the home country may then be written (for ease of notation we ignore the state notation here)

$$\begin{aligned}(K^{\alpha}h^{1-\alpha} - vN) = (1-s)\Bigg[&\left(\frac{p}{P}\right)^{-\rho} n(C+V+G) \\ &+\left(\frac{p}{eQ}\right)^{-\rho}(1-n)(C^*+V^*+G^*)\Bigg] \\ &+ s\Bigg[\left(\frac{p}{P}\right)^{-\rho} n(C+V+G) \\ &+\left(\frac{q}{Q}\right)^{-\rho}(1-n)(C^*+V^*+G^*)\Bigg].\end{aligned} \tag{1.22}$$

The expression on the left-hand side gives the level of average output per capita for the home country. This is smaller the higher is the fixed cost per sector, vN. The first expression on the right-hand side indicates that demand for the non-PTM good depends on its price relative to the price the home consumer faces, P, and separately, the price the foreign consumer faces (in home-currency units), eQ. Here we are using the properties of demand implied by the constant elasticity of substitution (CES) aggregator for C, V, and G.[7] Likewise, for the PTM firms, the second expression indicates that demand depends on prices facing the home consumer and the foreign consumer separately.

A similar market-clearing equation holds for the foreign country:

$$
\begin{aligned}
\left(K^{*\alpha} h^{*1-\alpha} - vN\right) = (1-s)\Bigg[&\left(\frac{eq^*}{P}\right)^{-\rho} n(C+V+G) \\
&+\left(\frac{q^*}{Q}\right)^{-\rho}(1-n)\left(C^*+V^*+G^*\right)\Bigg] \\
&+ s\Bigg[\left(\frac{p^*}{P}\right)^{-\rho} n(C+V+G) \\
&+\left(\frac{q^*}{Q}\right)^{-\rho}(1-n)\left(C^*+V^*+G^*\right)\Bigg].
\end{aligned}
\tag{1.23}
$$

Note finally that using the defined subprice indices above, we may write the CPI definitions for the home and foreign country as

$$P(z^t) = \left[np(z^t)^{1-\rho} + (1-n)sp^*(z^t)^{1-\rho} + (1-n)(1-s)eq^*(z^t)^{1-\rho}\right]^{1/(1-\rho)}, \tag{1.24}$$

$$Q(z^t) = \left[(1-n)q^*(z^t)^{1-\rho} + nsp(z^t)^{1-\rho} + n(1-s)\left(p(z^t)/e(z^t)\right)^{1-\rho}\right]^{1/(1-\rho)}. \tag{1.25}$$

Equilibrium

We may characterize the equilibrium of the two-country economy by collecting the equations set out above. First, for the case of complete asset markets, equations (1.3), (1.6) (with (1.5) substituted in for $w(.,.)$), (1.7), (1.8), (1.14), (1.15), (1.18), (1.19), (1.20), and (1.21), all with their counterparts for the foreign economy, as well as equations (1.10), (1.22), (1.23), (1.24), and (1.25), give twenty-five equations. This represents a dynamic system in the twenty-five unknown variables given by $X(z^t)$, where

$$
\begin{aligned}
X(z^t) = \{&C, C^*, h, h^*, V, V^*, K, K^*, W, W^*, R, R^*, p, q, p^*, q^*, P, Q, \tilde{p}, \tilde{q}, \\
&\tilde{p}^*, \tilde{q}^*, MC, MC^*, e\}.
\end{aligned}
$$

In the economy with incomplete markets, equation (1.10) is replaced with equation (1.11). Moreover, because there is not full risk sharing, we must determine the initial allocation of consumption across countries, which requires use of the balance-of-payments equation (1.4). Given (1.13), we may rewrite (1.4) as

$$
\begin{aligned}
&P(z^t)C(z^t) + q(z^t)B(z^t) + P(z^t)V(z^t) + P(z^t)G(z^t) \\
&\quad = \int_0^{n(1-s)} p(i, z^t)y^1(i, z^t)di + \int_{n(1-s)}^{n} \left[p(i, z^t)y^2(i, z^t)\right. \\
&\quad \left. + e(z^t)q(i, z^t)y^3(i, z^t)\right]di + B(z^{t-1})
\end{aligned}
\tag{1.26}
$$

Equation (1.26) is explained as follows. The left-hand side is the value of current home-country expenditure on consumption, investment, and government goods, plus the value of new bond purchases from the rest of the world. The right-hand side measures the value of output of all home-country firms, plus the value of initial bonds. Note that home-country firms consist of non-PTM firms and PTM firms, and these must be summed separately. The variable $y^1(i, z^t)$, for instance, measures the output of all firms in sector i, when i is a non-PTM sector.

In general, there will be no easy way to aggregate output values across firms to simplify the right-hand side of (1.26), because different sectors will be changing prices at different times. However, in solving the model, we take a linear approximation around an initial steady state. In that linear approximation, we can aggregate across sectors directly.

To conclude, we write that the solution for the economy with incomplete markets represents twenty-six equations in the variables $X'(z^t)$, where

$$X'(z^t) = \{C, C^*, h, h^*, V, V^*, K, K^*, W, W^*, R, R^*, p, q, p^*, q^*, P, Q, \tilde{p}, \tilde{q}, \tilde{p}^*, \tilde{q}^*, MC, MC^*, e, B(z^t)\}.$$

We solve the model by linearizing around an initial zero-shock steady state.

Calibration

The calibrated parameters for the baseline case are reported in table 1.1. The rationale for the calibration is as follows. For a quarterly frequency, β is chosen to equal 0.99, which gives a 4 percent steady-state annual real interest rate (abstracting from long-run growth). The value of η is

Table 1.1
Calibrated parameters for baseline case

β	0.99	α	0.36	n	0.5
σ	7	δ	0.025	s	0, 1.
ε	8.2	ν	1.1	γ	0.75
ς	1	μ	0.06	ϕ	0.025
η	3	μ^*	0.06	ϕ'	0.02
ρ	1.9	θ	0.2		
λ	10	θ^*	0.2		

chosen so that the representative agent in both countries elects to work 30 percent of available time, the standard calibration in real business cycle models.

The parameters ε and σ govern the consumption and interest elasticity of money demand. The consumption elasticity of money demand is equal to σ/ε. The interest elasticity of money demand is $\beta/\varepsilon(1+\mu)$. These two elasticities are critical for the response of the real and the nominal exchange rate to monetary shocks. Mankiw and Summers (1986) estimate a consumption elasticity of money demand almost precisely equal to unity. Other estimates have been reported, both higher and lower. Helliwell, Conkerline, and Lafrance (1990) report a large number of estimated money demand elasticities for G7 countries that are typically used in macro models. These differ somewhat across countries, but for many countries the income elasticity for narrower definitions of money is below unity. For instance, the reported Fair and Taylor (1983) model uses an estimated elasticity for M1 of 0.85 for the United States and 0.55 for Japan.

We choose parameters for our baseline case so that $\sigma/\varepsilon = 0.85$, consistent with Fair and Taylor's estimate. Estimates of the interest elasticity of M1 vary from a value of 0.02 reported in Mankiw and Summers 1986 to values around 0.25 reported in Helliwell, Conkerline, and Lafrance 1990. We choose a value of 0.12, which is approximately halfway between these estimates. With the annual money growth rate equal to 6 percent, this requires a relatively low intertemporal elasticity of substitution, that is, $\sigma = 7$.

We set the markup parameter λ so that markups are equal to those found by Basu and Fernald (1994) for U.S. data, that is, in the region of 10 percent. This requires a high elasticity of substitution between goods within sectors. On the other hand, we set the elasticity of substitution between sectors so that the elasticity of substitution between foreign and domestic goods (ρ) is equal to 1.5, the number used in Backus, Kehoe, and Kydland 1994. The steady-state depreciation rate of capital is set at 10 percent per year, so that $\delta = 0.025$. The fixed-cost parameter ν is then set to produce average profits of zero, in accordance with evidence of very small pure profits in the U.S. economy.

The share of government in GDP is set at 0.2, and the relative size parameter is set at 0.5, so that each country is of equal size. The price adjustment parameter is set so that the firm's average frequency of price adjustment is approximately four quarters. This requires $\gamma = 0.75$.

In the steady state, the adjustment cost function ϕ must equal the rate of depreciation. In addition, we also need to set the elasticity of Tobin's q (which is $1/\phi'$) with respect to investment. The higher is this elasticity, the greater time it takes to adjust the capital stock. Following Baxter and Crucini 1993, we set this elasticity so that the variability of investment relative to output in the simulated model is at reasonable levels.

Finally, we vary the pricing-to-market parameter, s, between 0 and 1.

Quantitative Evaluation of the Model

We now explore the characteristics of the calibrated model by deriving the theoretical impulse responses to monetary and government spending shocks. The figures show the response of eight key variables: the real exchange rate, output levels, the nominal interest rate differential, consumption, the terms of trade, prices, investment levels, and the nominal exchange rate. The responses for other variables, such as the trade balance or interest rate differentials can be inferred from the variables illustrated in the figures. Results are derived for both complete and incomplete markets and for the economy with and without PTM.

Monetary Shocks

Figures 1.3–1.6 describe the impact of an unanticipated, permanent one percentage point expansion in the home country money supply, beginning in a steady state. Figures 1.3 and 1.4 represent the $s = 0$ case, for complete and incomplete markets, respectively, and figures 1.5 and 1.6 the $s = 1$ case, for complete and incomplete markets, respectively.

As to be expected, when $s = 0$, there is no real exchange rate effect of a monetary disturbance, since even with sticky prices, PPP holds at all times. The monetary expansion causes an immediate permanent depreciation in the nominal exchange rate in exact proportion to the increase in money (figure 1.3b). It follows, since uncovered interest rate parity must hold in this economy, that the monetary shock does not change the interest rate differential. Since prices take some time to adjust to the money shock (figure 1.3e), the nominal exchange rate depreciation causes a change in the terms of trade. How do the terms of trade respond? In the $s = 0$ case, export prices are invoiced in home currency and import prices in foreign currency. Thus a nominal depreciation causes a deterioration in the terms of trade (figure 1.3d). The fall in the

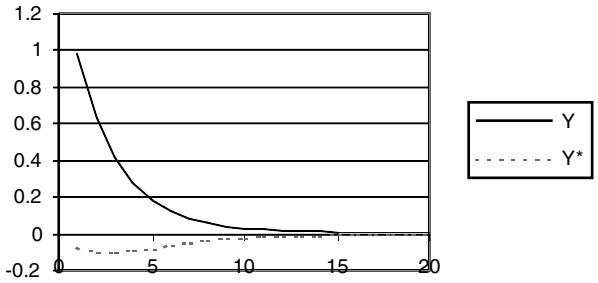

Figure 1.3a
Output

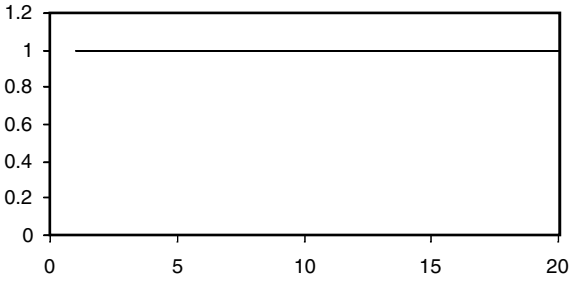

Figure 1.3b
Nominal exchange rate

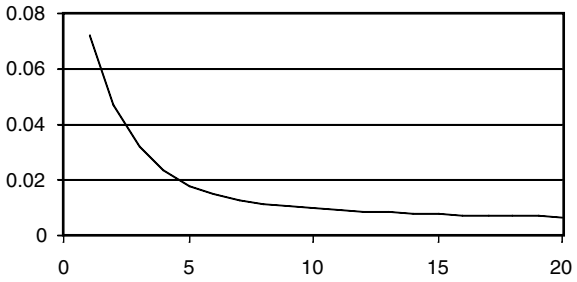

Figure 1.3c
Consumption

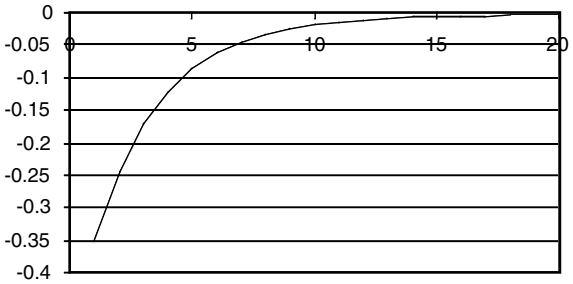

Figure 1.3d
Terms of trade

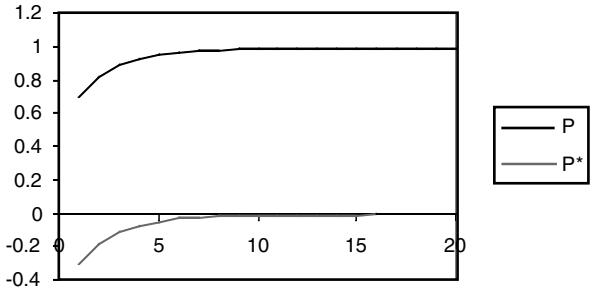

Figure 1.3e
Price levels

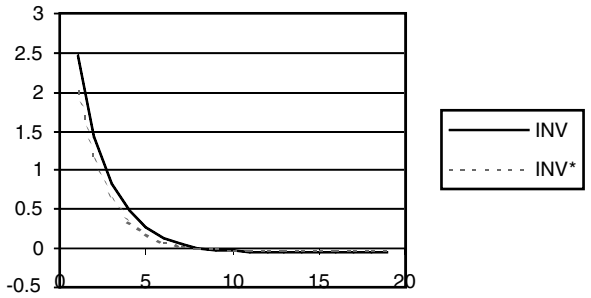

Figure 1.3f
Investment

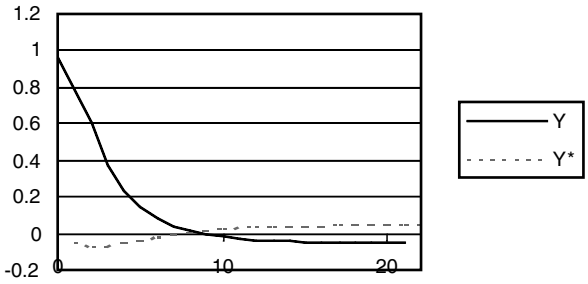

Figure 1.4a
Output

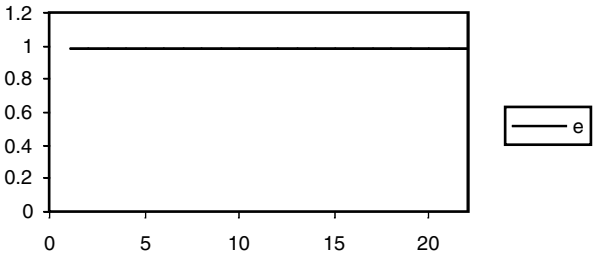

Figure 1.4b
Nominal exchange rate

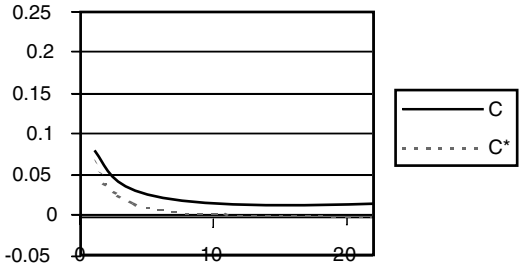

Figure 1.4c
Consumption

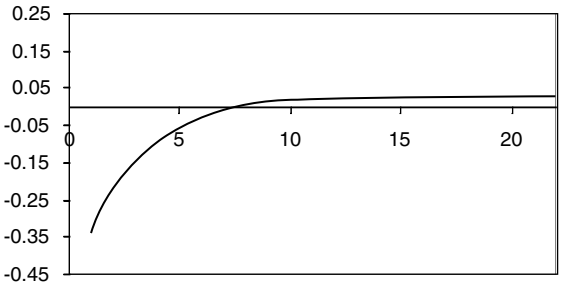

Figure 1.4d
Terms of trade

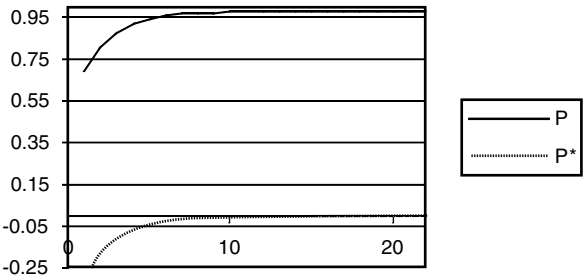

Figure 1.4e
Price levels

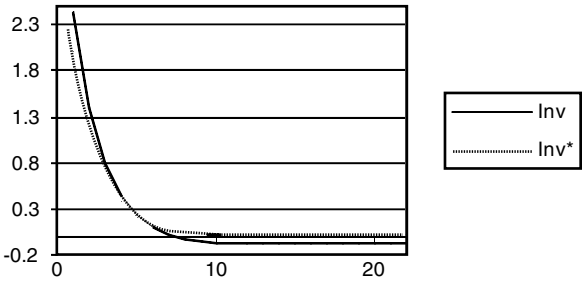

Figure 1.4f
Investment

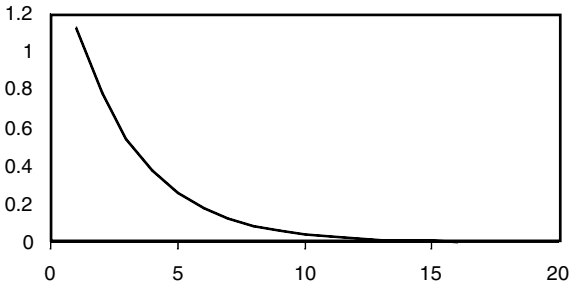

Figure 1.5a
Real exchange rate

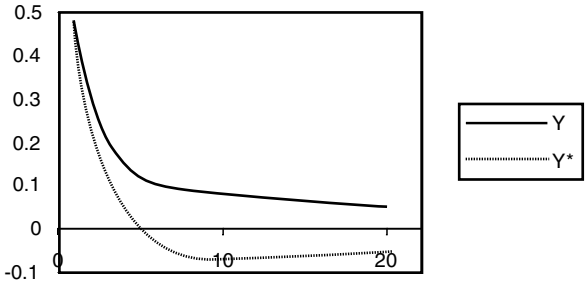

Figure 1.5b
Output

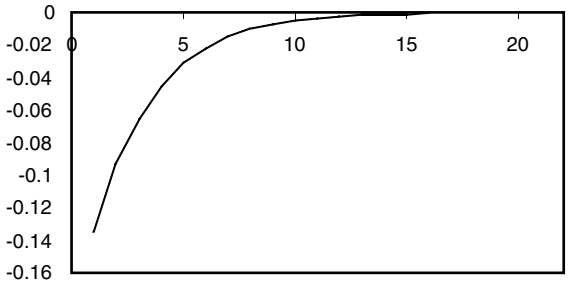

Figure 1.5c
Interest rate differential

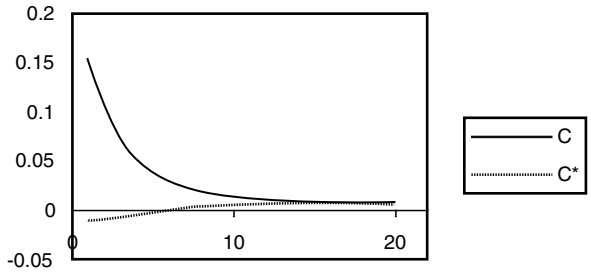

Figure 1.5d
Consumption

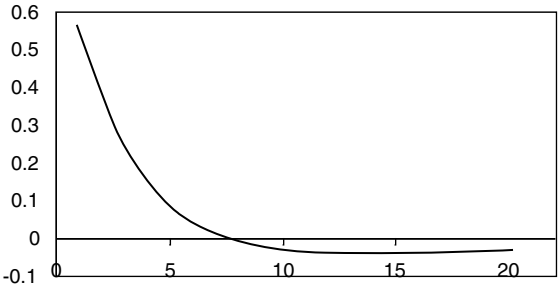

Figure 1.5e
Terms of trade

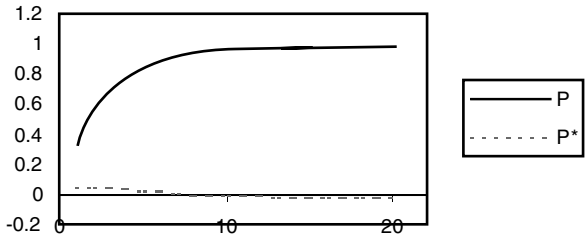

Figure 1.5f
Price levels

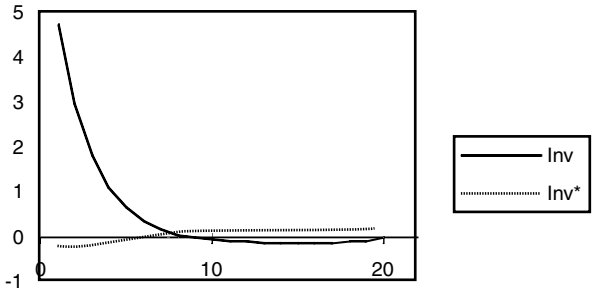

Figure 1.5g
Investment

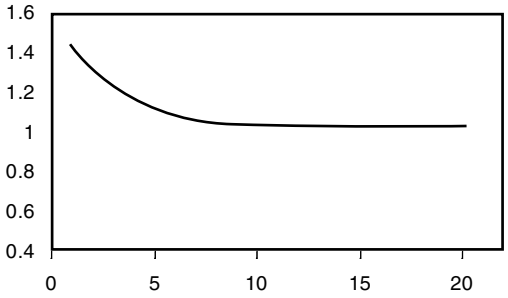

Figure 1.5h
Nominal exchange rate

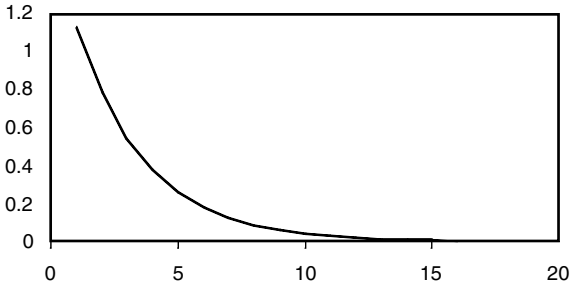

Figure 1.6a
Real exchange rate

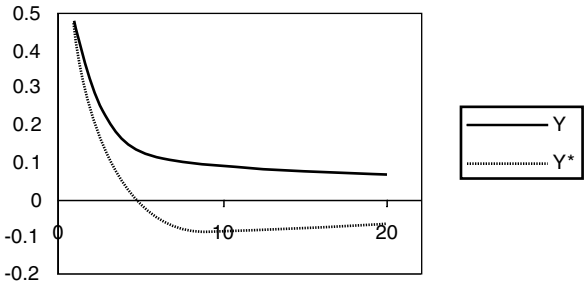

Figure 1.6b
Output

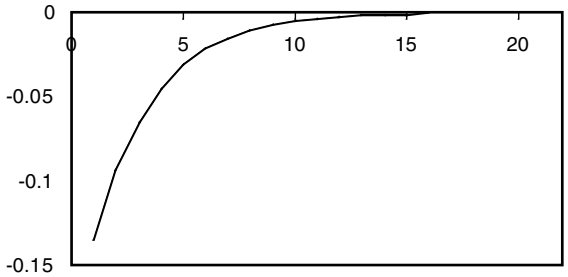

Figure 1.6c
Interest rate differential

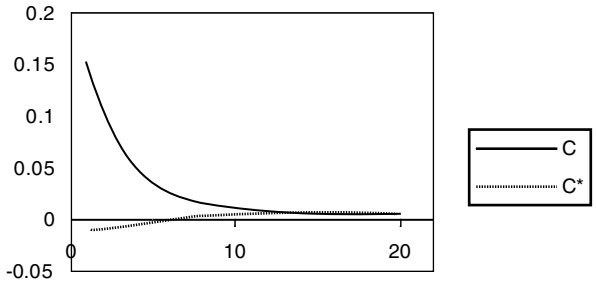

Figure 1.6d
Consumption

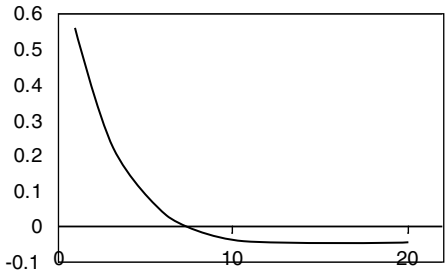

Figure 1.6e
Terms of trade

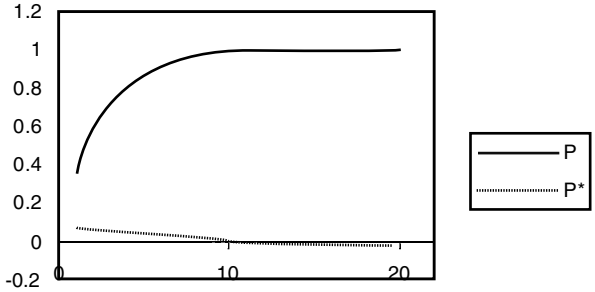

Figure 1.6f
Price levels

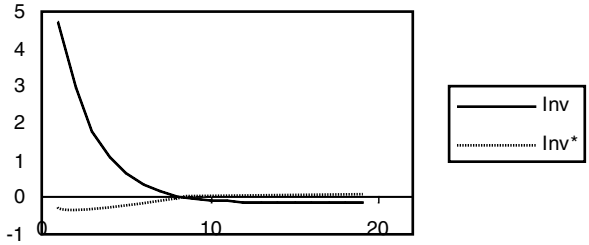

Figure 1.6g
Investment

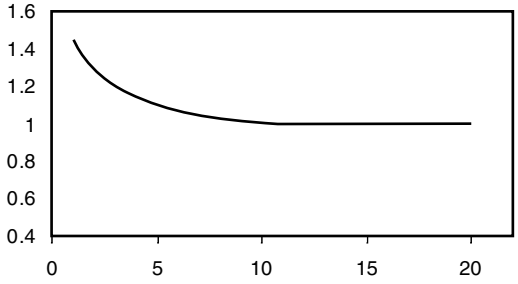

Figure 1.6h
Nominal exchange rate

terms of trade causes an "expenditure switching" of world demand away from the foreign country toward the home country. As a result, home output rises and foreign output falls (figure 1.3a). The international transmission of monetary policy in the $s = 0$ case is negative, for reasons essentially identical to Mundell 1968. Note that even though output levels move in different directions, consumption moves in the same way in both countries because of complete risk sharing (figure 1.3c). Consumption rises immediately but then gradually falls back to its steady-state level.

This illustrates the importance of differentiating output responses from consumption or welfare responses, a point emphasized by OR. In fact, in this complete markets economy, the home country will have lower welfare than the foreign country as a result of the monetary expansion, since home agents must work to produce a higher level of home output, which will be shared equally with consumers abroad.[8]

Finally, note that investment will rise in both countries (figure 1.3f). Since real interest rates can be inferred directly from the rate of growth of consumption (which in this case is equated across countries), we can deduce from figure 1.3c that the home monetary expansion reduces real interest rates in both countries. This stimulates an increase in investment expenditure.

How important are financial markets in generating these results? Let us now investigate the effects of monetary policy shocks when there is only trade in noncontingent nominal bonds. This is the market structure that is used in OR. Obstfeld and Rogoff show that an unanticipated monetary expansion will lead to a less than proportional rise in the nominal exchange rate and a home-country trade surplus, which leads to a permanent increase in home consumption, relative to foreign consumption. Figure 1.4 illustrates the result for our model in the case of incomplete markets. As before, of course, there is no impact on the real exchange rate when $s = 0$. The nominal exchange rate now rises slightly less than proportionally to money. Again, the terms of trade fall, precipitating an expenditure switching toward the home-country output, with a negative international transmission. But now there is a slightly larger increase in home consumption than foreign consumption (figure 1.4c), as the first-period home-country trade account surplus increases home assets, leading to a permanent carrying forward of home wealth into the future. The relatively large increase in home consumption implies that steady-state output is lower in the

home economy (figure 1.4a) because of the wealth effects of consumption on labor supply.

We notice that in comparing figure 1.3 with figure 1.4, the asset market structure makes little difference to the central properties of the international monetary transmission mechanism. Although consumption does not respond in identical ways here, the pattern of response is almost identical in both countries. Quantitatively, the difference in the exchange rate's response between the two asset market structures is very small (1 as opposed to 0.99). Because of the persistence of the initial current account surplus, the home country will have a permanently larger steady-state consumption, as emphasized in OR. But quantitatively, the difference in consumption levels is miniscule. A 1 percent surprise increase in the home-country money supply increases steady-state home-country consumption by less than 0.01 percent of its initial level.

Figures 1.5 and 1.6 illustrate the case of monetary policy under pricing-to-market for complete and incomplete markets, respectively. Since PPP does not hold in the short run, the real exchange rate now responds to an unanticipated monetary shock. The shock immediately causes a real and nominal exchange rate depreciation (figures 1.5a and 1.5h). In fact the nominal exchange rate now "overshoots," rising more in the short run than in the long run. This causes a fall in the nominal interest rate differential (figure 1.5c). The movement in the real exchange rate causes consumption responses to diverge, even in the complete markets case (figure 1.5d), since with $s = 1$, optimal risk sharing is conditioned on movements in the real exchange rate (see equation (1.10)).

The response of the terms of trade is now the opposite of the $s = 0$ case. All exports are invoiced in foreign currency and imports in domestic currency. An exchange rate depreciation therefore raises the relative price of exports, that is, it improves the terms of trade (figure 1.5e). The monetary shock also now has an opposite impact on foreign output than in the $s = 0$ case. The presence of full pricing-to-market implies that there is no immediate pass-through from exchange rates to prices. Thus, an exchange rate depreciation has no expenditure-switching impact. Rather, there is a balanced expansion in demand for the goods of both the home and foreign country. Output of the home and foreign country rise by equal amounts initially (figure 1.5b). Following this, home-country output remains higher for a period, because the monetary disturbance expands home-country investment.

Finally, we see that investment rises in the home country while falling slightly in the foreign country (figure 1.5g). In the presence of departures from PPP, there is no longer equality of real interest rates between countries. As can be deduced from the changes in consumption growth rates, home real interest rates fall, while foreign rates rise slightly.

Thus the currency of pricing is a critical factor in the direction of the international transmission of monetary policy on output. Unlike the Mundell 1968 or the OR specification, an exchange rate depreciation with local currency invoicing of export prices does not generate negative international output transmission. In general, comparing the effects of monetary policy across the two different pricing regimes, we see there are substantial differences in international transmission. The direction of movements in output, consumption and investment, and the terms of trade are reversed when we move from the $s = 0$ case to the $s = 1$ case.

However, comparing figures 1.5 and 1.6, as well as figures 1.3 and 1.4, it is apparent that the asset market structure makes almost no difference to the international monetary transmission mechanism, with our without pricing-to-market.

It seems valid to conclude that for monetary policy transmission, the critical dichotomy is the currency of invoicing. Relative to this, the structure of international assets markets is much less important.

When we compare figures 1.5 and 1.6 to the empirical impulse responses for output levels, real exchange rates, and nominal interest rates as described in figures 1.1 and 1.2, a number of things are apparent. First, the theoretical monetary transmission mechanism in the $s = 1$ case captures the positive cross-country correlation of output in the data. Second, the theoretical results for the $s = 1$ case also reflect the positive and persistent impact of the money shock on the real exchange rate. Finally; the model with $s = 1$ also seems to capture well the effects of monetary policy shocks on nominal interest rate differentials. Thus the empirical international monetary transmission mechanism seems to be in accord with the economy in which pricing-to-market is predominant.

Government Spending Shocks

We now turn to the analysis of government spending policies, as illustrated in figures 1.7 and 1.8. The first thing to note is that in the case of

complete markets, government spending shocks have identical effects on all home and foreign variables. Unlike in the classic Mundell model, government spending is not exclusively allocated to home-country goods but involves purchases of the composite consumption good.[9] That is, an increase in either country's government spending increases the demand for all goods produced in the home and foreign country. When markets are complete, both the home and foreign country share equally the wealth effects of financing this increased expenditure. The responses of output, consumption, and investment are then identical to those in a closed economy (e.g., Barro 1987). Both home and foreign output rise, stimulated by an increase in employment and investment, and consumption falls. There is no response in either the real or the nominal exchange rate (even in the $s = 1$ case), and there are no effects on the terms of trade or the trade balance. Moreover, because of the absence of exchange rate effects, the currency of invoicing is irrelevant. The degree of pricing-to-market has no consequences at all for the impact of fiscal policy shocks in the complete markets economy.

If markets are incomplete, however, government spending shocks have quite a different impact. An expansion in home-country government spending now leads to a permanent increase in the home consumer's tax bill, which is not shared with foreign consumers through coinsurance arrangements, as in the complete markets case. Home-country consumers reduce their consumption (figure 1.7c) and expand labor supply in response to the fall in real wealth. Home output rises, and since employment is higher, home investment is stimulated, leading to further increases in output over time (figure 1.7a).

When $s = 0$, the government spending shock has no real exchange rate effects, but the rise in home output leads to a terms-of-trade deterioration for the home economy (figure 1.7d), which is exacerbated over time as home output continues to rise. Thus, the government spending increase causes a permanent increase in home output and a permanent fall in the terms of trade.

What impacts are there for the foreign country? Initially, the rise in government spending will increase foreign output, since demand for foreign products rise, and prices are sticky. However, as prices adjust, the wealth effects of higher terms of trade and higher consumption begin to come into force. Foreign labor supply falls, and foreign output falls to a permanently lower level (figure 1.7a). Thus, the initial stimulation of foreign output is reversed in the new steady state. By contrast,

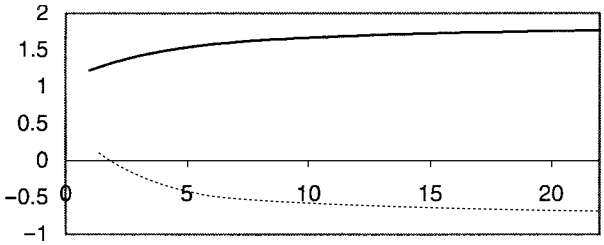

Figure 1.7a
Output

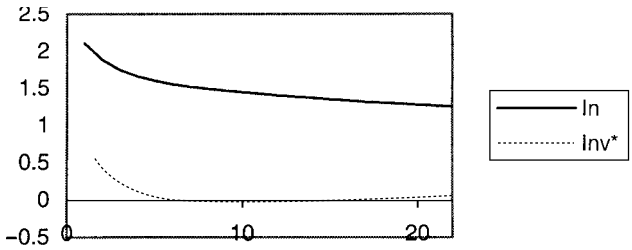

Figure 1.7b
Investment

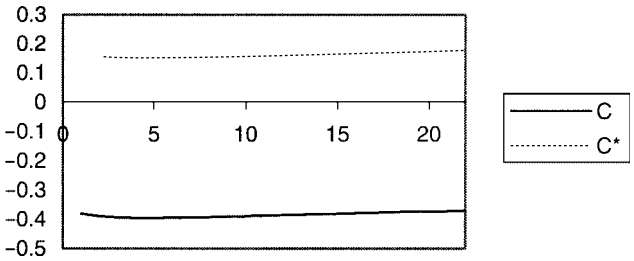

Figure 1.7c
Consumption

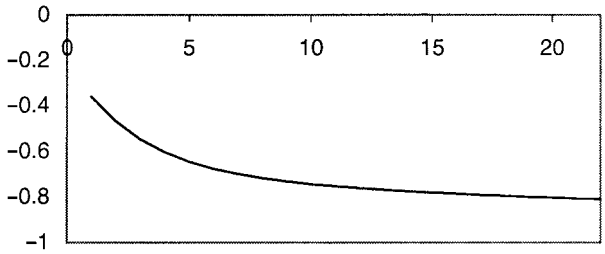

Figure 1.7d
Terms of trade

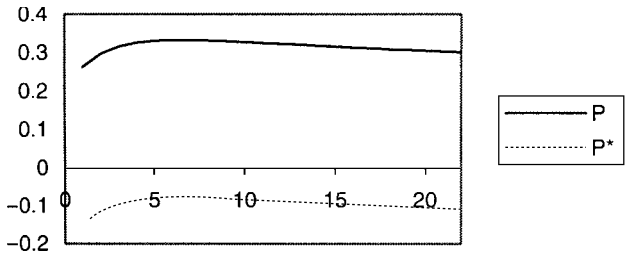

Figure 1.7e
Price level

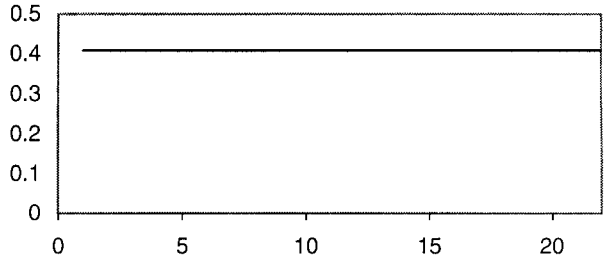

Figure 1.7f
Nominal exchange rate

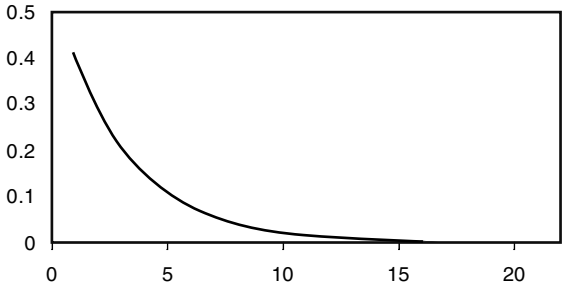

Figure 1.8a
Real exchange rate

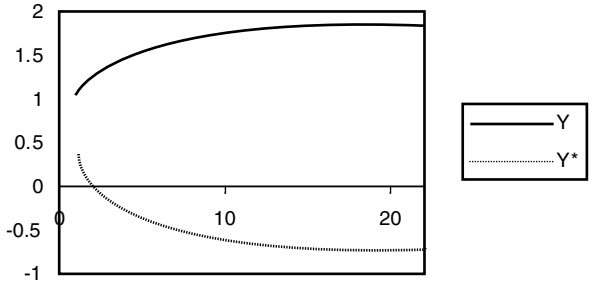

Figure 1.8b
Output

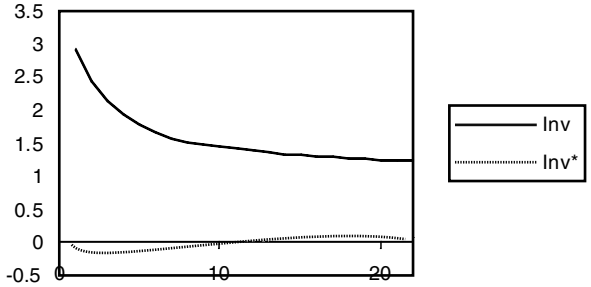

Figure 1.8c
Investment

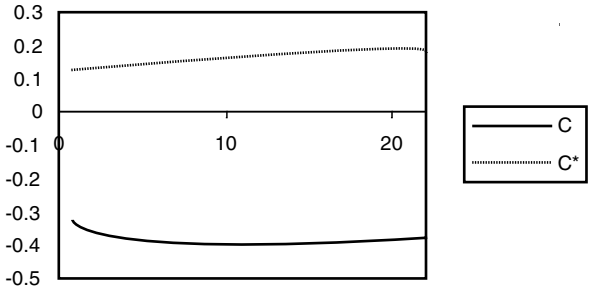

Figure 1.8d
Consumption

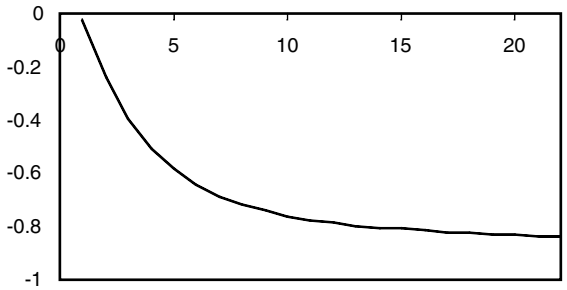

Figure 1.8e
Terms of trade

with permanently higher terms of trade, foreign consumption is higher in the new steady state.

A fiscal expansion also affects the nominal exchange rate (as shown also by OR). To restore money market equilibrium in the face of an increase in foreign consumption and a fall in domestic consumption, the domestic CPI must rise and the foreign CPI must fall. From the PPP conditions, this requires a nominal exchange rate depreciation that is both immediate and permanent.

Figure 1.8 illustrates the effects of fiscal policy with pricing-to-market ($s = 1$). The impact is almost the same as the $s = 0$ case, save for the response of the real and nominal exchange rate. With no immediate pass-through of the exchange rate to domestic and foreign prices (figure 1.8f), the foreign price level does not move at the time of the shock, and the rise in the home price level is smaller than in the $s = 0$ case. As a result, both the fall in home consumption and the rise in

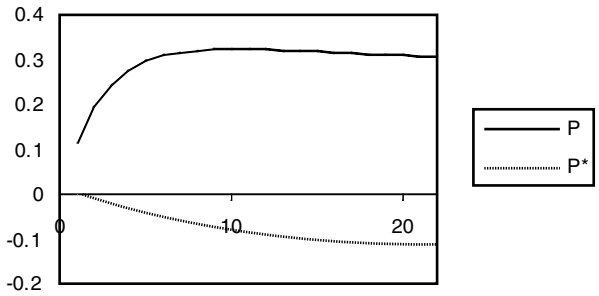

Figure 1.8f
Price level

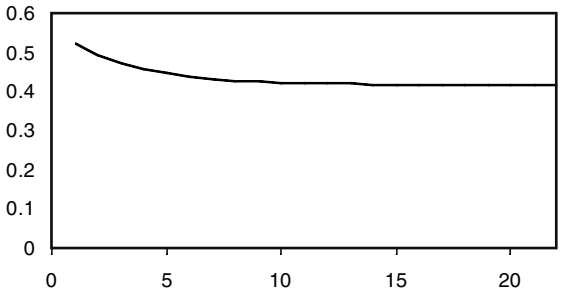

Figure 1.8g
Nominal exchange rate

foreign consumption are slightly smaller than in the $s = 0$ case (figure 1.8d). The nominal exchange rate then rises by more in the short run than in the long run (figure 1.8g), and the real exchange rate immediately depreciates (figure 1.8a). The reduced effect on consumption implies a smaller movement in labor supply, which reduces the magnitude of the output responses for both countries (figure 1.8b).

Nevertheless, the main features of the international transmission of fiscal shocks remain unaffected by changes in the currency of invoicing. We still see an immediate, positive cross-country transmission in output initially and a negative transmission in consumption. The terms of trade deteriorate, and the nominal exchange rate depreciates.

In contrast to the case for money shocks, however, the structure of asset markets is now of key importance for understanding the international transmission of fiscal shocks. If asset markets are complete,

there are no exchange rate effects, no terms-of-trade effects, and no differential output or consumption responses to a home-country fiscal policy disturbance.

Discussion

We may then draw the following conclusions from our analysis. When we reexamine the central questions of Mundell 1968 in light of modern intertemporal optimizing sticky-price models, the impact of money shocks on the international transmission process relies not on the structure of asset markets but rather on the currency of invoicing, or the degree of pricing-to-market. When export prices are preset in the currency of the buyer rather than that of the seller, the international transmission of monetary policy is significantly altered. However, when asset markets are limited to noncontingent bonds trade rather than allowing full consumption coinsurance, the implications for the monetary transmission process are quite minor. One way to interpret the result is that moving from the simple assumption of capital mobility, used by Mundell and the subsequent literature, to a world of more sophisticated financial integration does not significantly alter the macroeconomic effects of monetary policy.

The consequences for fiscal policy are just the opposite. Approximately, the currency of invoicing has no implications for fiscal policy shocks. Changes in the currency of invoicing leave the main elements of the international policy transmission mechanism unchanged. On the other hand, changes in the asset market structure have substantial effects on the nature of the fiscal policy transmission mechanism. If agents cannot coinsure across countries, the effects of fiscal policy are fundamentally different than those in the complete markets environment.

Conclusions

This chapter has built on a number of recent contributions in international macroeconomics to examine a time-honored question in the field: the international transmission effects of monetary and fiscal policy. Mundell's (1968) contribution became the benchmark for thinking about this problem. Our results indicate that when we reexamine the effects of monetary and fiscal policy in a modern framework, paying careful attention to asset markets and pricing, we find some important

differences from earlier analysis, and we obtain some clear insights that would not have been available using earlier approaches. In particular, we find that the critical issue pertaining to the international effects of monetary policy is the currency of export pricing, whereas the critical issue regarding the effects of fiscal policy is the structure of asset markets.

Notes

1. This new literature has grown very quickly. An important early paper was Svensson and van Wijnbergen 1989. More recent contributions include Bergin 1995, Corsetti and Pesenti 1998, Chari, Kehoe, and McGrattan 1997, Kollman 1997, Hau forthcoming, Senay 1998, Stockman and Ohanian 1997, and Tille 1998. Lane 1998 provides an insightful survey into this area.

2. Since we do not have a widely agreed identifying scheme for government spending shocks, in the empirical investigation we restrict our attention to the effects of monetary shocks.

3. For a review of this methodology, see Betts and Devereux 1998.

4. This initial negative response, although very small in our results, is consistent with evidence established in the closed-economy versions of this empirical characterization of monetary policy shocks presented by Christiano and Eichenbaum 1995, and with open-economy versions such as Schlagenhauf and Wrase 1995.

5. These results are available upon request from the authors.

6. Since we are not allowing for state-contingent pricing, the difference between the objective functions turns out to be unimportant for the pricing decision in any case.

7. We assume that governments minimize the cost of producing a given amount of the final government good G, or G^*.

8. This statement is based on the assumption that changes in the supply of real-money balances have welfare effects sufficiently small that they can be ignored.

9. Tille 1998 examines the impact of government spending in a two-country model under the alternative assumption that government spending is biased more toward domestic goods.

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