

PRINCETON STUDIES IN INTERNATIONAL FINANCE NO. 44

**Currency Risks in  
International Financial Markets**

**Clas Wihlborg**

**INTERNATIONAL FINANCE SECTION  
DEPARTMENT OF ECONOMICS  
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PETER B. KENEN  
*Director*

*Princeton University*

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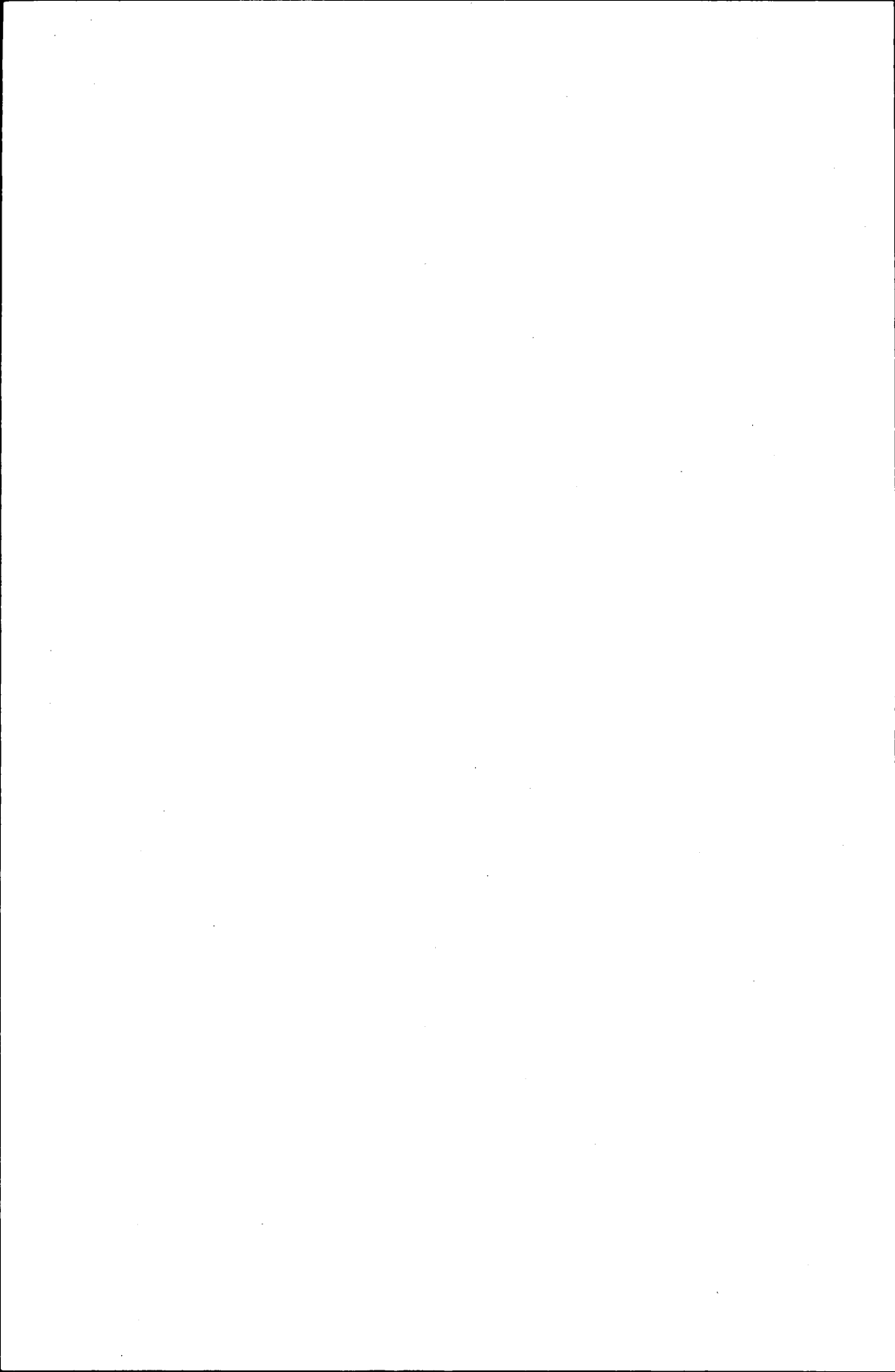
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## 1 INTRODUCTION

The relative riskiness of holding foreign currency under flexible and fixed exchange-rate regimes has always been a major consideration when the costs and benefits of each regime have been compared. Interest has centered on risk because of its welfare implications and its effect on the efficiency of stabilization policies.

One important concern is that the costs of financing international trade increase if investors and traders consider it risky to hold foreign currencies, making the international division of labor less efficient. Two other concerns relate to the efficiency of international capital markets. First, an exchange-rate regime may cause welfare losses if real rates of return differ on similar investments in different countries because of the riskiness of holding foreign currencies. Second, an exchange-rate regime may limit the opportunity to diversify portfolios so as to minimize exposure to currency risks.

A particular level of risk need not be inherent in an exchange-rate regime: it may be the deliberate result of central-bank policies. The target of minimizing risk may conflict with other policy considerations. Such a conflict occurs, for example, when the central bank tries to control the real rate of interest on domestic financial assets. The bank's ability to do so is largely determined by the degree of substitutability of domestic and foreign assets. By adopting an exchange-rate regime that increases currency risks, the central bank can decrease the substitutability of assets denominated in different currencies and thereby increase the effectiveness of monetary policy.

There is thus ample reason to study the size and nature of the risks associated with international borrowing and lending under different exchange-rate regimes and to determine the extent to which the risks under these regimes are subject to control by monetary authorities. The purpose of this study is to try to clarify the issues by analyzing (a) how the risks of investing in alternative currencies can be described; (b) how the size and the nature of the risks depend on the exchange-rate regime and on the behavior of the monetary authority under each regime; and (c) how risks and changes in the levels of risk affect the behavior of investors. At issue is whether an investor's response to changes in rates of return or risks somehow depends on the exchange-rate regime.

Chapter 2 states the assumptions of the analysis and clarifies certain concepts that must be understood before the analysis of risk can proceed.

The risk analysis and exchange-rate regimes are described, and a distinction is made between currency risks and country risks. The analysis deals mainly with currency risks, i.e., the risks associated with the choice of currency in which an investment is denominated. Currency risks are then divided into three kinds, inflation risk, exchange-rate risk, and a relative-price risk. Finally, the concept of purchasing power parity is explained.

In Chapter 3, risks are analyzed under assumptions about the relationships between the exchange rate, relative-price levels, and relative prices. It is shown that there is a major difference between the risks faced by investors in the presence of purchasing power parity (PPP) and those faced if there is uncertainty about deviations from PPP. It is also shown that exchange risk depends on how closely the exchange rate is correlated with the terms of trade.

In Chapter 4, some recent models of exchange-rate determination are used to evaluate the importance of the different risks under flexible, adjustable-peg, and fixed-exchange-rate regimes. Each kind of risk can exist under any regime. The models of exchange-rate determination provide certain qualitative results, but these are not sufficient to evaluate completely how risks depend on exchange-rate regimes. Reference must also be made to empirical evidence of actual exchange-rate and price relationships and to the behavior of monetary authorities.

In order to draw conclusions about the effects of risks on trade and international capital markets, it is necessary to determine how investors are likely to respond to changing magnitudes and kinds of risk. In Chapter 5 (and in the Appendix), a simple mean-variance analysis is used to examine the effects of risks on investor choice. Conclusions are then drawn about the effects of risks on the substitutability of assets denominated in different currencies and on the efficiency of markets for assets denominated in particular currencies.

The analysis in Chapters 3, 4, and 5 is based on certain assumptions (presented in Chapter 2) about the assets among which investors can choose. In Chapter 6, however, it is pointed out that structural developments have occurred in international financial markets that may be a response to higher risks. Examples of such developments are the increase in borrowing and lending in multi-currency bonds and in assets with non-rigid nominal rates of interest. The role of forward markets is also discussed in this chapter.

Finally, Chapter 7 summarizes the analysis, and the policy issues raised above are discussed briefly with the analysis of risk as a background.

## 2 ASSUMPTIONS, PRELIMINARIES, AND DEFINITIONS

### 2.1 *Assumptions*

The analysis adopts the perspective of an investor in country A and considers his investment opportunities. It is also applicable to many transactions of traders, however, since traders become investors or borrowers whenever the date of payment for goods does not coincide with the date of delivery. The analysis is also applicable to multinational corporations and other investors with activities in several countries, but in such cases it is important to define the "habitat" of the investor. (This will be discussed below under assumption d).

Four major assumptions concerning the behavior of investors are maintained throughout the analysis:

a. Investors choose their portfolios by maximizing expected utility at a target date. The expected real rate of return on the portfolio enters utility positively, while risk enters negatively. This means that each investment opportunity is evaluated on the basis of its expected real rate of return, the level of risk, and the correlation between its rate of return and the rates of return on alternative investments.

b. The probability distributions of all stochastic variables are assumed to be normal. The main stochastic variables are the anticipated rates of change of exchange rates and of the rates of inflation. The arithmetic mean of the anticipated rate of change is called the expected rate of change. The second moments of the probability distributions are the variances. These variances are used to measure the levels of risk. (The levels of exchange rates and prices are lognormally distributed when the rates of change are normally distributed. The analysis is much simplified and the main points are clear under this assumption, although there are cases in which it is unrealistic.)

c. The nominal rate of interest on each asset is fixed and known with certainty at the time of purchase. If the nominal rates of interest were not fixed, the correlation between nominal rates of interest, expected exchange-rate movements, and expected inflation rates would have to be considered. In Chapter 6, this extension is discussed.

d. At the target date of the investment, the investor switches to his domestic currency, i.e., he can purchase goods and services only by using the domestic currency. It is a simplification to employ the term "domestic" for the currency that is used to buy goods and services. The point is that the investor has to switch to the currency of the country in which he is

going to purchase goods and services. For example, the domestic currency of the multinational firm is not the currency of the country where the head office is located. Rather, the multinational firm has many "domestic" currencies, depending on where commodities and services are to be purchased.

Although the domestic currency is normally the currency of issue in the home country, residents of that country might accept as means of payment more than one currency at current exchange rates. The analysis below could be generalized to cover this case, but it would then be necessary to distinguish between inflation rates in countries and inflation rates in currencies. The price of a commodity in a certain currency would depend on the country in which its price was quoted. The individual who made a future contract in nominal terms in a particular currency would always have to be concerned about both the future exchange rates and the future price level in the country of purchase.

## 2.2 Description of the Risk Analysis

There are two countries, A and B. An investor in either country has a choice between assets issued in country A or B. The A asset is denominated in the currency of country A and the B asset in the currency of country B. The assets are identical in all respects except for the country of origin and the currency of denomination. In other words, asset characteristics do not depend on the specific firms or municipalities issuing assets.

Since investors are assumed to maximize expected utility, the model must explicitly identify the expected real rate of return and the associated risk for each type of investment. The table below indicates how these variables are defined given the habitat of the investor and the country of origin of the asset.

The nominal interest rates on the assets are known at the time of the investment, according to assumption c. For any investor, the nominal interest rate on the A asset is  $r_A^N$ , and the nominal interest rate on the B asset is  $r_B^N$ . However, the expected nominal rate of return on any *foreign* investment also depends on the expected rate of change in the exchange rate ( $\hat{X}$ ), defined in units of A currency per unit of B currency. The expected *real* rates of return on the investments are equal to the nominal rates of return minus the expected rate of inflation in the country of habitat.<sup>1</sup>

---

<sup>1</sup> It is, in fact, an approximation to set the real rate ( $r$ ) equal to the difference between  $r^N$  and  $\hat{P}$ . The exact version is the following:  $(1 + r) = (1 + r^N)/(1 + \hat{P})$ . One term ( $r \cdot \hat{P}$ ) is set equal to 0. Qualitatively, the analysis is not influenced by this approximation.

VARIABLES DEFINING THE CHARACTERISTICS OF ASSETS ISSUED IN DIFFERENT  
COUNTRIES FOR INVESTORS WITH DIFFERENT HABITATS

<i>Investor's Habitat</i>	<i>Investing in Asset of</i>	
	<i>Country A</i>	<i>Country B</i>
<b>Country A:</b>		
Expected nominal rate of return	$r_A^N$	$r_B^N + \hat{X}$
Expected real rate of return	$r_A^N - \hat{P}_A$	$r_B^N + \hat{X} - \hat{P}_A$
Uncertainty about	$\hat{P}_A$ ; country A characteristics	$\hat{P}_A$ ; $\hat{X}$ ; country B characteristics
<b>Country B</b>		
Expected nominal rate of return	$r_A^N - \hat{X}$	$r_B^N$
Expected real rate of return	$r_A^N - \hat{X} - \hat{P}_B$	$r_B^N - \hat{P}_B$
Uncertainty about	$\hat{P}_B$ ; $\hat{X}$ ; country A characteristics	$\hat{P}_B$ ; country B characteristics

**DEFINITION OF SYMBOLS:**

$r^N$  = nominal rate of return

$\hat{X}$  = expected rate of change in exchange rate

$\hat{P}$  = expected rate of inflation

Subscripts *A* and *B* denote country.

The risks associated with the investments depend in all cases on uncertainty about the inflation rate in the country of habitat. On investments in foreign currencies, there is additional uncertainty about the rate of change of the exchange rate. Finally, depending on which country issues the asset, there is uncertainty about laws, regulations, and property rights. These aspects of investment in a country are called "country characteristics" in the table.

It is desirable to distinguish uncertainty about country characteristics from uncertainty about inflation rates and exchange rates, since assets issued in any major European country can be denominated in many currencies. Risks associated with uncertainty about inflation rates or exchange rates are thus called "currency risks." Risks that depend solely on the country of issue are called "country risks."

In order to take country risks into account, it would be necessary to extend the range of alternatives in the table to assets issued in one country but denominated in the other country's currency. In section 2.4, however, it is argued that country risks and currency risks are largely independent. Country risks are therefore neglected in the analysis.

It is important to note that the analysis in Chapter 3 is explicitly partial. The variables are identified on which an investor is expected to base his decision to invest a certain proportion of his wealth in the domestic cur-

rency and certain proportions in foreign currencies. These variables are the expected real rates of return and the variances of these returns, since investors are assumed to be risk-averse maximizers of expected utility (assumption a). Investors individually take as given nominal interest rates, the expected rate of inflation, and the expected rate of change of the exchange rate. They must then evaluate the variances of, and the correlation between, real rates of return on domestic and foreign investments. The analysis in Chapter 3 proceeds by identifying whether it is the variance of the exchange rate, of the inflation rate, of deviations from PPP, or of a relative price that constitutes the risk on an investment in a particular currency. No attempt is made to derive the market relationships between risks and relative rates of return. It must also be noted that the relationships among the exchange rate, the inflation rates, and the terms of trade are simply assumed.

Once the variables on which the risks on alternative investments depend are identified, it is natural to extend the analysis in two ways. First, in Chapter 4, a few models of exchange-rate determination are studied in order to ascertain the risks on foreign and domestic investments given the particular assumptions employed by different models. The second extension, in Chapter 5, develops the market-equilibrium consequences of the risks. It asks, for example, how changes in the levels of risk affect relative demands and therefore equilibrium rates of return, and how the level of risk affects the response of investors to changing relative rates of return.

The interdependence among risks, returns, and the relative demand for domestic and foreign assets is analyzed within a simple two-asset mean-variance model. This model is in equilibrium when the outstanding supplies of foreign and domestic assets are willingly held.

### 2.3 *Definitions of Exchange-Rate Regimes*

I distinguish between four exchange-rate regimes: (a) fixed exchange rates without bands, (b) fixed exchange rates with bands, (c) adjustable pegs, and (d) flexible exchange rates.

a. A fixed exchange rate is a rate *known* to be fixed for the foreseeable future. Regime (a), the fixed rate without bands, cannot exist between countries with independent central banks. If there is no band within which the exchange rate can fluctuate, and if the rate is known forever, we have in effect a currency area similar to the one within a single country. The fixed rate without bands highlights the monetary-policy aspect of the choice of exchange-rate regime. Since regime (a) necessitates a common monetary policy, any difference between the rates of return on assets

denominated in the two currencies will induce capital flows. Thus, common monetary policies must be carried out, and common inflation rates will result. In other words, the correlation between inflation rates must be close to 1 under regime (a), and the variances of the inflation rates must be similar. It follows, of course, that there can be no difference in the risks associated with holding a "foreign" currency and the domestic currency, just as no greater currency risk is incurred by holding dollars in California instead of in New York. (For political or other reasons, however, the California investment may differ from the New York investment.)

b. As soon as there are bands within which a fixed rate can fluctuate, we have a qualitatively different regime from the point of view of the issues studied here. Uncertainty about the future exchange rate enters the picture. Even a band as narrow as 1 per cent can lead to considerable uncertainty for short-term investors. A maximum change in the exchange rate of 1 per cent over one month implies an annualized rate of change of 12 per cent, while the same maximum change over a ten-year-period implies an annualized rate of change of the magnitude of 0.1 per cent. Clearly, the longer the time horizon of an investment, the less important is the band relative to rates of return. Therefore, the longer the time horizon, the more this exchange-rate regime approaches the one without bands.

Under regime (b), there must be at least an implicit agreement on monetary policies in participating countries. In the short run, however, there is some monetary independence and inflation rates and variances of inflation rates need not be identical. But, again, the correlation between inflation rates must approach 1 over the long run, and the variances of the inflation rates must be similar.

c. An adjustable peg can be described as a regime under which the exchange rate may fluctuate within a band and discrete adjustments of the exchange rate can be made too. With this regime, there is no restriction on the monetary policies of different countries and on the correlation between the inflation rates. The less policies are coordinated and the more inflation rates diverge, however, the more often and the larger must be the discrete adjustments. A feature of this regime that distinguishes it from a flexible rate is that uncertainty about the peg is a necessary part of the regime. Central banks typically decide to adjust the peg in secret in order to avoid massive short-term capital movements. Were the adjustments to be announced ahead of time, nominal interest rates would have to respond immediately with a corresponding change. In addition, along the lines of prevailing theories of stabilization policy, large adjustments are made in order to change the relationship between real wages and profits. If announcements of impending adjustments were made,

firms and individuals would anticipate the changes and possibly nullify the desired effects. (A technical problem of measuring risks arises under this regime. Variances of normal distributions were identified with risks above. Under this regime, however, the distribution of anticipated changes of the exchange rate may at times approach a binomial distribution; anticipations are such that either the peg is not adjusted or it is adjusted by a large amount [see Schilling, 1970]. I argue below, however, that the assumption of a normal distribution still provides the right direction of change in magnitudes.)

d. The flexible-exchange-rate regime may be dirty or clean, i.e., with or without central-bank intervention. The key feature of this regime is that the exchange rate can change continuously without fixed rules. Monetary policies may or may not be coordinated between countries, and inflation rates may or may not be similar. The main point is that monetary policies and inflation rates are independent. The correlation between inflation rates may be high or low, and the variances of inflation rates may be of similar magnitudes or very far apart. However, it can be argued that the longer the time horizon, the more likely it is that the correlation between inflation rates will be low. The fact that central banks are independent makes it extremely unlikely that they will carry out identical policies at all times.

When three of the exchange-rate regimes are compared in terms of the nature and magnitudes of risks (fixed rates without bands are excluded), flexible rates are at one extreme and fixed rates with bands at the other. The fixed rate requires coordinated monetary policies and highly correlated inflation rates except in the very short run. The flexible rate implies that monetary policies and inflation rates are independent but not necessarily uncorrelated. The adjustable peg can be viewed as a mixture of these two regimes. In the short run, when the peg is believed to hold, it is like a fixed regime. In the long run, it is like a flexible regime since monetary policies are independent and inflation rates need not be correlated. The most specific feature of an adjustable peg is that there can at times be expectations that the exchange rate will remain fixed and at times expectations that it will change by a large amount.

#### *2.4 Definitions of Risks: Distinguishing Currency Risks from Country Risks*

With the development of the Eurocurrency markets, it has become desirable to distinguish between country risks and currency risks. It can be argued that country risks to some extent depend on exchange-rate regimes or in some way may increase because of attempts to lower cur-



rency risks. When country risks are carefully defined, however, the grounds for such arguments become very weak.

*Currency risks.* Currency risks are divided into three categories, inflation risk, exchange-rate risk, and a relative-price risk.

Inflation risk is the variance of the real rate of return caused by the variance of the inflation rate of the currency in which the investment is denominated. Inflation risk is symmetric: investors in all countries are affected by it, as we shall see below.

Exchange-rate risk, or exchange risk, is the variance of the rate of return caused by the variance of the rate of change of the exchange rate *without* corresponding changes of the inflation rates, i.e., by the variance of the rate of change of deviations from PPP. We shall see that this is an asymmetrical risk specific to foreign investments.

When exchange-rate changes are correlated with relative-price changes between goods produced domestically and abroad, we have relative-price risk. It is caused by the variance of a relative price and therefore depends on the consumption bundle of the investor and not on the habitat.

This clear distinction between risks associated solely with currencies and risks that depend solely on the consumption bundle is difficult to maintain in all cases. However, it seems desirable to distinguish risks that depend on uncertainty about nominal variables—inflation rates and the exchange rate viewed as the relative price of currencies—from risks that depend on real variables, i.e., relative prices.

*Country risks.* Country risks are divided into political risk, default risk, and “real capital” risk.

Countries can be regarded as more or less risky to lend to when investors are uncertain about future regulations and laws regarding taxes, exchange controls, moves toward socialism, etc. Basically, these political risks depend on uncertainty about the extent of property rights.

Uncertainty about exchange controls is a critical link between uncertainty about property rights and exchange-rate regimes. Some have argued that exchange controls are more likely to be imposed under fixed and pegged exchange rates than under floating rates. But central banks may consider short-term exchange-rate fluctuations under a flexible regime to be just as serious as fluctuations of the balance of payments under a fixed-rate regime. They may therefore opt to control capital flows under either regime. Economists disagree about whether a flexible rate *can* be stabilized by controls, but controls have certainly been recommended by some (see, e.g., Cooper, 1976). On the other side, McKinnon (1976), for example, has argued that free, short-term capital movements are necessary for a smoothly functioning flexible-rate regime.

Default risk on a country level has been discussed lately in connection

with the debt burdens of many developing countries and some European countries. In order for a country to go into bankruptcy, its debts must be denominated in foreign currencies. (Otherwise, its central bank can inflate the debt away, unless it has made a long-term commitment to a fixed exchange rate.) Bankruptcy will occur if the country does not produce enough resources to buy the foreign exchange necessary to repay the debts. This kind of default risk is, of course, very extreme. More important, probably, is the default risk that a country will refuse to meet its obligations. In either case, it is the real capacity of the economy that determines a country's ability to repay debts. There are no grounds for believing that the exchange-rate regime is a major determinant of the long-run productive capacity of an economy.

The currency denomination of a debt determines which kind of risk lenders face. When the debt is denominated in the borrowing country's currency, lenders face the risk that inflation in the borrowing country may decrease the real value of its debt, a currency risk. When the debt is denominated in the lenders' currency or in some other foreign currency to which the borrower's currency is not fixed, lenders face the risk that the borrowing country will not meet its obligations, a country risk. The currency denomination of the debt therefore determines whether lenders face a currency risk or a country risk.

"Real capital" risk can be defined as uncertainty about the general economic development of a country, about the average real rate of return on capital or the rate of profit. This risk, of course, is particularly important for equity investments and for investments in assets with flexible nominal rates of return. To the extent that there is a short-run tradeoff between inflation and profit rates, i.e., to the extent that nominal wages are rigid, this kind of risk will be difficult to distinguish from inflation risk. What is said below about the relationship between inflation risk—a currency risk—and the choice of exchange-rate regime will then carry over to this country-specific risk. But the choice of regime cannot change a real capital risk into a currency risk.

## *2.5 The Concept of Purchasing Power Parity (PPP)*

In this study, PPP is defined from conditions of equilibrium in international commodity markets. Under PPP, competition is perfect in the markets for all goods and services and prices of all goods are the same everywhere, i.e., the law of one price holds for all commodities. Perfect arbitrage for all commodities is a sufficient condition for PPP to hold. Statistical measures of price indices can deviate from PPP when taste

patterns (weights) differ, but, since relative prices will be the same in all countries, the marginal rates of substitution between commodities will also be the same everywhere. If one could construct a price index free of the influence of "pure" relative-price effects, it would show PPP when the law of one price holds. The fact that this cannot be done is likely to exaggerate empirical measures of deviations from PPP.

For several reasons, PPP defined in this way does not hold in the real world. In Chapter 3, currency risks are analyzed for each of the following reasons for deviations from PPP:

a. Indirect taxes make prices deviate from PPP even when the law of one price holds for net price levels.

b. Imperfect commodity arbitrage makes the law of one price invalid for short or long time periods.

c. Nontraded goods are extreme cases of imperfect commodity arbitrage. When the degree of deviation from the law of one price in response to exchange-rate fluctuations is not uniform across commodities, exchange-rate movements generate relative-price changes. In section 3.4, currency risks are analyzed for one such case—under the assumption that, in each of two countries, there is one traded good, for which commodity arbitrage is perfect, and one nontraded good, for which there is no commodity arbitrage.

d. Tariffs can be regarded as a special case of indirect taxes. However, the introduction of tariffs leads to terms-of-trade changes. One of the cases in section 3.5 is an analysis of currency risk when the exchange rate is correlated with the terms of trade and the law of one price holds for all commodities. Uncertainty about tariffs can be viewed as a combination of uncertainty about indirect taxes and uncertainty about the terms of trade; therefore, it will not be treated as a separate case.

The time dimension of deviations from PPP is important in the analysis of risk. For goods that are traded internationally, violations of the law of one price are probably limited. Once the price difference between two countries is greater than the transport cost for the product involved, there are incentives for arbitrage. In analogy with the gold points, Heckscher (1916) coined the term "commodity points" for the band within which the price of a commodity in one country can deviate from the price of the identical commodity in another country. In addition to transport costs, such a band can be caused by import monopolies, commodity standards, and imperfect information. We can thus imagine a band within which there can be deviations from PPP defined in terms of *levels* of prices and the exchange rate. The existence of such a band implies that the margin for changes in deviations from PPP is constant over all time horizons.

Expressed as the percentage rate of change in deviation from PPP per year, the maximum deviation must then decline with the length of time considered.

When there are nontraded goods, international trade obviously cannot maintain PPP completely. If, for example, commodity arbitrage causes the prices of traded goods to rise after a depreciation while the prices of nontraded goods are unaffected, there will be a deviation from PPP. But, again, there are forces working to restore PPP. As long as consumer tastes and production technology are unchanged, the relative prices between commodities must return to their initial (equilibrium) level. Otherwise, there will be a demand shift toward nontraded goods and a production shift away from nontraded goods. The new exchange rate cannot then be an equilibrium rate. Either the prices of nontraded goods must increase or the prices of traded goods must fall. In both cases, PPP is restored.

As in the case of deviations from PPP for traded goods, there are limits to the possible deviations here: the more relative prices change, the stronger is the demand/supply shift. Again, we can say that a band around PPP requires the percentage rate of change possible per year in the deviation from PPP to be smaller the longer the time horizon.

### 3 CURRENCY RISKS, PURCHASING POWER PARITY, AND THE TERMS OF TRADE

#### 3.1 *Perfect Commodity Arbitrage in a One-Good World*

Assume commodity arbitrage is perfect, so that PPP holds, and investors base their expectations on it. Assume also that there is only one commodity or there are no relative-price changes.

The expected real rate of return on a country A investment for an A resident is the nominal rate of interest in A ( $r_A^N$ ) minus the expected rate of inflation ( $\hat{P}_A$ ). The expected real rate of return on a country B investment for an A resident ( $r_B$ ) is the nominal rate of interest in B ( $r_B^N$ ) plus the expected rate of appreciation of the B currency ( $\hat{X}$ ) minus the expected domestic rate of inflation ( $\hat{P}_A$ ). Assuming PPP ( $\hat{X} \approx \hat{P}_A - \hat{P}_B$ ), the real rate of return on the B investment is simply the nominal rate of interest in country B minus the expected rate of inflation in country B:

$$\begin{aligned} r_A &\approx r_A^N - \hat{P}_A \\ r_B &\approx r_B^N - \hat{P}_B. \end{aligned} \tag{1A}$$

Inflation in country A does not affect the A investor's real rate of return on the investment in currency B, because the loss in real value due to inflation in A is exactly offset by an appreciation of B's exchange rate. Instead, country B's inflation determines the rate of return on the B investment, because B's exchange rate depreciates with inflation in B.

When nominal interest rates are known, the variances of the two real rates of return are

$$\begin{aligned} \sigma_A^2 &= \sigma_{\hat{P}_A}^2 \\ \sigma_B^2 &= \sigma_{\hat{P}_B}^2, \end{aligned} \tag{1B}$$

where  $\sigma_A^2, \sigma_B^2$  = the variances of the real rates of return on the two investments for the A resident

$\sigma_{\hat{P}_A}^2, \sigma_{\hat{P}_B}^2$  = the variances of the two inflation rates.

Equations (1B) say that the risk on the investment in the domestic currency is the variance of the domestic inflation rate and the risk on the investment in the foreign currency is the variance of the foreign inflation rate. The first part needs no explanation. The explanation of the second part is that the A investor investing in B is protected against an unanticipated rise in the A price level, because any such change will cause B's

currency to appreciate. However, an unanticipated rise in the price level in B affects the purchasing power of the investment, because B's currency depreciates with the inflation in B. The risk on the investment in currency B is therefore equal to the variance of the inflation rate in country B. This is true for the A investor and obviously also for the B investor. The risks are symmetrical in the sense that they are independent of the residency of the investor.

In this PPP world, there is nothing we can call exchange risk as it was defined in Chapter 2. Exchange risk cannot be looked upon as simply a risk due to uncertainty about the exchange rate, although this is the most common view in the literature on the subject (see, e.g., Aliber, 1972, 1973, 1976; Kindleberger, 1963; Solnik, 1973; and Yeager, 1966). Yeager does, recognize, however, that uncertainty about exchange rates is uncertainty about nominal variables, and he shows that changes in the domestic price level can offset the "exchange risk" under certain circumstances. Clark (1973) shows that interdependence between the foreign price of a commodity and the spot exchange rate may make a foreign-currency investment with forward cover or a domestic investment more risky than an investment in a foreign currency without cover. It can be seen in equation (1B) that this would be the situation when the variance of the domestic inflation rate was higher than the variance of the foreign inflation rate.

The assumption that nominal rates of return are known when investments are made is very important. If the nominal interest rates on the two investments were perfectly linked to the rates of inflation (as by purchasing-power bonds), both investments would be completely risk-free when PPP holds. The A resident investing in an A bond would be protected against the domestic inflation risk by the link between the nominal interest rate and the inflation rate. If he invested in a B bond, he would be protected against domestic inflation risk by exchange-rate changes that would offset domestic inflation higher than foreign inflation and he would be protected against foreign inflation risk by the link between the foreign nominal return and the foreign inflation rate. There is inflation risk on investments in a particular currency only when the nominal interest rate is rigid to some extent with respect to the inflation rate.

### *3.2 Perfect Commodity Arbitrage in a One-Good World, with Indirect Taxes*

Perfect commodity arbitrage ensures that PPP will hold for *pre-tax* price levels and rates of price change. In the absolute version of PPP, an *ad valorem* tax makes price levels that include taxes deviate from PPP,

but in its relative version PPP still holds. It follows from the analysis in the previous section that when *ad valorem* taxes are known with certainty, the only risks to consider are inflation risks. However, when there is uncertainty about the *ad valorem* tax rates, investors face an additional source of uncertainty about the real rate of return on an investment.

Consider again an investor in country A who has a choice between two assets that are identical in all respects except the currency of denomination. The expected real rate of return on the A asset is the nominal rate ( $r_A^N$ ) minus the expected rate of inflation before tax ( $\hat{P}_A$ ) minus the effect of the expected rate of change of the tax rate in country A ( $\hat{t}_A$ , where  $t_A = \text{price including tax}/\text{price excluding tax}$ ). The expected real rates of return on the two investments are now

$$\begin{aligned} r_A &\approx r_A^N - \hat{P}_A - \hat{t}_A \\ r_B &\approx r_B^N - \hat{P}_B - \hat{t}_A. \end{aligned} \quad (2A)$$

The A investor's expected rate of return on the B investment is the nominal rate of interest in B ( $r_B^N$ ) minus the expected *pre-tax* inflation rate in B ( $\hat{P}_B$ ) minus the expected rate of change of the tax rate at home ( $\hat{t}_A$ ). As before, PPP for the pre-tax inflation rates means that the A investor is protected against changes in the domestic pre-tax price level by offsetting exchange-rate movements.

In comparing the riskiness of the two assets, the investor must still consider inflation risks for the two currencies. In addition, he faces uncertainty about the tax rate at home, but he has to face this uncertainty with all investments:

$$\begin{aligned} \sigma_A^2 &= \sigma_{\hat{P}_A}^2 + \sigma_{\hat{t}_A}^2 + 2\sigma_{\hat{P}_A} \cdot \sigma_{\hat{t}_A} \cdot \rho[\hat{P}_A; \hat{t}_A] \\ \sigma_B^2 &= \sigma_{\hat{P}_B}^2 + \sigma_{\hat{t}_A}^2 + 2\sigma_{\hat{P}_B} \cdot \sigma_{\hat{t}_A} \cdot \rho[\hat{P}_B; \hat{t}_A] \end{aligned} \quad (2B)$$

There is one reason why foreign-currency investments may now be riskier than domestic investments. The rate of change of the tax rate may be correlated with the pre-tax inflation rate at home, but it is unlikely to be correlated with the foreign pre-tax inflation rate. When the correlation between the domestic rate of pre-tax inflation and the change in the domestic tax rate is negative, an unanticipated increase in the tax rate is more or less offset by a decrease in the rate of inflation before tax. The behavior of the monetary authority and the degree to which it is willing to let the tax increase affect the rate of inflation including tax determine to a large extent whether there will be a negative correlation. To clarify, let us look at alternative ways in which the monetary authority may respond to a tax increase.

The monetary authority may let the tax increase raise the general price

level by increasing the money supply. In this case, the pre-tax price level and the exchange rate are not affected by the tax increase;<sup>1</sup> it follows that there is zero correlation between the domestic rate of inflation before tax and the rate of change of the tax.

Alternatively, the monetary authority may not allow the money supply to increase. The pre-tax price level will then have to fall, and the exchange rate will appreciate. The result is a negative correlation between the price level before tax and the tax increase. The risk associated with the domestic investment is smaller in this case than in the former, while the risk associated with the foreign investment is not affected by the behavior of the domestic monetary authority.

As when there are no indirect taxes, the currency risks accompanying the two investments stem mainly from uncertainty about the behavior of the monetary authorities of the two countries. In some cases, however, the behavior of the fiscal authorities has to be taken into account. For the investor in the foreign asset, inflation risk arises from uncertainty about the behavior of the foreign central bank with regard to the pre-tax foreign price level. In addition, he faces uncertainty about the behavior of the domestic fiscal authority. The investor in the domestic-currency asset confronts uncertainty about the behavior of the domestic central bank and uncertainty about the fiscal authority. However, if the central bank is concerned about the price level *including* taxes, the pre-tax price level and the tax level will be negatively correlated. The risk associated with the domestic investment is then reduced to the inflation risk, and the behavior of the fiscal authority becomes irrelevant.

In conclusion, indirect taxes constitute a risk for *foreign* investments under certain assumptions about the behavior of the monetary authorities. This risk does not derive from fluctuations in the exchange rate in general and should therefore not be called exchange risk. Actually, with the downward rigidity of wages and prices that is prevalent in almost all countries, the most likely case is that central banks as a rule will increase the money supply and let the price level rise with increases in indirect taxes. Accordingly, we will not pursue further the examination of risks on foreign investments associated with changes in domestic indirect taxes.

### 3.3 *Imperfect Commodity Arbitrage in a One-Good World*

A more interesting reason for deviations from PPP than indirect taxes is imperfect commodity arbitrage between countries. If there are imper-

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<sup>1</sup> Krauss (1977) discusses in another context the relationships among indirect taxes, exchange rates, and price adjustments.



fections in international commodity markets, the price of a commodity in country A may differ from the price of an identical commodity in country B. A change in the price level in A need not be reflected immediately in the exchange rate, and the exchange rate may change without a corresponding change in commodity prices.

The expected rate of change in the exchange rate ( $\hat{X}$ ) now has three parts—the expected rate of inflation in country A ( $\hat{P}_A$ ), the expected rate of inflation in country B ( $\hat{P}_B$ ), and the expected rate of change in the deviation from PPP ( $\hat{U}$ ):

$$\hat{X} \approx \hat{P}_A - \hat{P}_B + \hat{U}. \quad (3)$$

The expected real rates of return and the two alternative investments for the A investor can now be expressed in the following way:

$$\begin{aligned} r_A &\approx r_A^N - \hat{P}_A \\ r_B &\approx r_B^N - \hat{P}_B + \hat{U}. \end{aligned} \quad (4A)$$

The expected real rate of return on the A asset for the A investor is equal to the nominal interest rate minus the expected rate of inflation in country A, as before. The A investor's expected real rate of return on the B asset is now written as the nominal rate of interest in B minus B's rate of inflation plus the expected rate of change of the deviation from PPP, because, again, any exchange-rate change that corresponds to inflation in country A does not influence the real rate of return on the foreign investment.

The risk on the domestic investment arises, as before, from the variance of the domestic rate of inflation. A new element has been added to the risk on the foreign investment, however. In addition to the variance of the foreign inflation rate, the investor faces uncertainty about changes in the deviation from PPP:

$$\begin{aligned} \sigma_A^2 &= \sigma_{\hat{P}_A}^2 \\ \sigma_B^2 &= \sigma_{\hat{P}_B}^2 + \sigma_{\hat{U}}^2 - 2\sigma_{\hat{P}_B} \cdot \sigma_{\hat{U}} \cdot \rho(\hat{P}_B, \hat{U}), \end{aligned} \quad (4B)$$

where  $\sigma_{\hat{U}}^2$  is the variance of the rate of change in the deviation from PPP.

Assuming that the rate of change in the deviation from PPP is independent of the rates of inflation, uncertainty about the change in the deviation from PPP will cause a risk specific to foreign investments ( $\sigma_{\hat{U}}^2$ ): *Fluctuations in the exchange rate that are not immediately translated into changes in price levels constitute a risk on investments in foreign currencies.* This is exchange-rate risk. In contrast to inflation risk, the presence of exchange-rate risk on an investment in a certain currency depends on the habitat of the investor.

If these deviations are not independent of inflation rates, however, exchange-rate risk cannot be described simply as the variance of the rate of change in deviations from PPP. Expressions (4B) show that the covariance between the rate of inflation in country B and the rate of change in the deviation from PPP must also be considered. Assume, for example, a completely fixed exchange rate without bands. Given the price level in country A and the exchange rate, any increase in the price level in country B must imply a rise of the same magnitude in the deviation from PPP. For an A investor, the variance of an investment in the B currency becomes zero. If the domestic inflation rate is not given, the variance of the B investment will equal the variance of the domestic inflation rate. In both cases, there is no exchange risk when the future exchange rate is known. This is rather obvious. Exchange risk arises only when there is uncertainty about *exchange-rate fluctuations* around PPP. Uncertainty about *price fluctuations* around PPP does not cause exchange risk.

The question as to whether the variance of changes in deviations from PPP can be used to measure exchange risk is raised in Chapter 4 in connection with the discussion of risks under different exchange-rate regimes. The relative importance of inflation risk and exchange risk is also discussed there. At this point, we can conclude that the variance of the exchange rate itself is a theoretically incorrect measure of exchange risk. It is, however, an empirical issue whether, under some conditions, the variance of the exchange rate can be used as a proxy for the risk of investing in assets denominated in foreign currencies.

### 3.4 *Nontraded Goods*

In order to bring out the essential facts about inflation and exchange risks, it has been assumed heretofore that there is only one good. Inflation and exchange risks exist when there is perfect certainty about relative prices; they are therefore independent of the composition of the investor's consumption bundle.

Exchange-rate fluctuations may in the short run induce relative-price changes for goods with different distances between their "commodity points." Aliber (1976) termed the risk faced by investors because of these relative-price changes "price risk" to distinguish it from exchange risk. However, any risk associated with such uncertainty about a relative price between goods in slow and fast arbitrage cannot be clearly distinguished from exchange risk. Instead, the degree of exchange risk that investors face on investments in foreign assets depends on the consumption bundle. The easiest way to show this is to assume that there are two commodities in each country, one traded good, for which international markets work

perfectly, and one nontraded good, for which there is no international market at all.

The price level in country A can now be expressed as a weighted average of the price of the traded good ( $P_A^T$ ) and the price of the nontraded good ( $P_A^{NT}$ ). The expected real rates of return on investments in countries A and B can, as before, be expressed as the nominal rates of return minus the expected rate of inflation in A, expressed as a weighted average of the changes in the two prices:

$$\begin{aligned} r_A &\approx r_A^N - \alpha \hat{P}_A^T - (1 - \alpha) \hat{P}_A^{NT} \\ r_B &\approx r_B^N + \hat{X} - \alpha \hat{P}_A^T - (1 - \alpha) \hat{P}_A^{NT}, \end{aligned} \quad (5)$$

where  $\alpha$  is the share of the traded good in the A resident's consumption bundle. The rate of change of the exchange rate is in turn equal to the difference between the inflation rates in terms of *traded* goods.

The expected rates of return in the two countries can now be divided into two components by expressing the inflation rate in terms of the expected rate of change in the price level of the traded good as one component ( $\hat{P}_A^T$ ) and the expected rate of change of the relative price as the second component ( $\hat{S} \approx \hat{P}_A^T - \hat{P}_A^{NT}$ ). The following expressions are derived from (5) by setting  $\hat{X} \approx \hat{P}_A^T - \hat{P}_B^T$  and inserting the expression for  $\hat{S}$ :

$$\begin{aligned} r_A &\approx r_A^N - \hat{P}_A^T + (1 - \alpha) \hat{S} \\ r_B &\approx r_B^N - \hat{P}_B^T + (1 - \alpha) \hat{S}. \end{aligned} \quad (6A)$$

The expected real rate of return on an investment in a certain currency is here expressed as the nominal interest rate in that currency minus the expected inflation rate of traded-goods prices in the same currency plus a term expressing how much the price of the nontraded good falls relative to that of the traded good in the domestic market.

The risks of the two investments can be expressed in the following way:

$$\begin{aligned} \sigma_A^2 &= (\sigma_{\hat{P}_A^T})^2 + (1 - \alpha)^2 \cdot \sigma_{\hat{S}}^2 - 2(1 - \alpha) \cdot \sigma_{\hat{P}_A^T} \cdot \sigma_{\hat{S}} \cdot \rho(\hat{P}_A^T, \hat{S}) \\ \sigma_B^2 &= (\sigma_{\hat{P}_B^T})^2 + (1 - \alpha) \sigma_{\hat{S}}^2 - 2(1 - \alpha) \cdot \sigma_{\hat{P}_A^T} \cdot \sigma_{\hat{S}} \cdot \rho(\hat{P}_B^T, \hat{S}). \end{aligned} \quad (6B)$$

The variance of each investment consists of the variance of the inflation rate in terms of the traded good in the country of investment plus the variance of the rate of change in the domestic relative price minus the covariance between these two variables. When there is no correlation between the relative price and the inflation rates in terms of traded goods, the difference in risk between the two investments will simply depend on the variances of the inflation rates in terms of traded goods, as in the PPP case. However, there will be a risk specific to foreign investments

when the covariance between the relative price and the *domestic* price of the traded good is larger than the covariance between the relative price and the *foreign* price of the traded good. This is the most likely case, because the domestic price of the traded good is actually a part of the domestic relative price. A rise in the price of the traded good in country A implies a change in relative price too.

An intuitive explanation for this risk on foreign investments is that fluctuations in the domestic price of the traded good affect only a part ( $\alpha$ ) of the real value of an investment in the domestic currency, while fluctuations in the foreign price of the traded good, corresponding to changes in the exchange rate, cause fluctuations in the whole real value of an investment in the foreign currency. Investing in a foreign currency protects against unanticipated changes in the domestic price of the traded good but not against unanticipated changes in the price of the nontraded good.

Another way to describe the foreign-currency risk in this case is to say that there is uncertainty about deviations from the law of one price for a part of the consumption bundle. The investor faces exchange risk on this part when investing in a foreign currency. As in the case of uniform deviations from PPP on all goods (section 3.3), exchange risk is caused by uncertainty about the rate of change in deviations from PPP. When there are nontraded goods, the change in the deviation from PPP corresponds to a relative-price change. Therefore, the amount of exchange risk faced by investors depends on the consumption bundle.

### 3.5 *Terms-of-Trade Effects of Exchange-Rate Changes*

Heckerman (1973) studies the currency risks associated with domestic and foreign investments in a two-country, two-commodity model in which the exchange rate is correlated with the terms of trade. One commodity is produced in country A and the other in country B. The future price of the commodity produced in A is known with certainty in country A, and the future price of the commodity produced in B is known in country B, but the exchange rate is uncertain. The law of one price is assumed to hold, i.e., commodity arbitrage is perfect for both commodities. The price of the imported commodity fluctuates with the exchange rate under these assumptions, so that a country's terms of trade deteriorate with a devaluation. By investing in the asset denominated in the domestic currency, a resident of country A can make a risk-free investment in terms of the domestically produced commodity, since its future price is known. The risk on the domestic investment in terms of the commodity produced

abroad is equal to the variance of the exchange rate, since the future price of this commodity is known only in the foreign country. By investing in assets denominated in the foreign currency, however, the country A investor can make the investment risk-free in terms of the foreign good. An increase in the domestic price of the foreign good exactly corresponds to an appreciation of the foreign currency. Heckerman's conclusion is that an investor can avoid risk by investing a part of his wealth in an asset denominated in the foreign currency when the foreign good is part of his consumption bundle.

As in the case of PPP, without relative-price changes there is no risk specific to foreign investment in this case. Country A and country B investors face no risk on the share of wealth reserved for A (or B) goods if they invest in the country where the price of the A (or B) good is known with certainty, i.e., in the country where the good is produced, in the Heckerman case.

The analysis of risks when the terms of trade are correlated with the exchange rate can be generalized further. Assume that a price index for A residents consists of two goods, the domestically produced good A and the foreign good B. The expected inflation rate can then be expressed as a weighted average of the expected rates of change of the two prices:

$$\hat{P}_A = \alpha \hat{P}_A^A + (1 - \alpha) \hat{P}_A^B, \quad (7)$$

where  $\alpha$  is the share of good A in country A and the superscript denotes the good. Assume also perfect commodity arbitrage for each good, so that the rate of change of the exchange rate is equal to the difference between the rates of change of the price of each commodity in the two currencies:

$$\hat{X} \approx \hat{P}_A^A - \hat{P}_B^A \quad \text{and} \quad \hat{X} \approx \hat{P}_A^B - \hat{P}_B^B. \quad (8)$$

The expected real rates of return on the two investments are the nominal interest rates corrected for expected exchange-rate movements and the expected domestic inflation rate. As there is perfect commodity arbitrage for each commodity, the expected real rate of return on an investment in the B currency can be expressed solely in terms of the expected rate of change of prices in country B:

$$\begin{aligned} r_A &\approx r_A^N - \alpha \hat{P}_A^A - (1 - \alpha) \hat{P}_A^B \\ r_B &\approx r_B^N - \alpha \hat{P}_B^A - (1 - \alpha) \hat{P}_B^B. \end{aligned} \quad (9A)$$

The variance of an investment in a certain currency can now be expressed as a weighted average of the variances of the rates of change in

the prices of the two commodities in the currency of the investment plus the covariance between the two rates of change:

$$\begin{aligned}\sigma_A^2 &= \alpha^2(\sigma_{\hat{P}_A^A})^2 + (1 - \alpha)^2 \cdot (\sigma_{\hat{P}_A^B})^2 + 2\alpha(1 - \alpha) \cdot \sigma_{\hat{P}_A^A} \\ &\quad \cdot \sigma_{\hat{P}_A^B} \cdot \rho(\hat{P}_A^A, \hat{P}_A^B) \\ \sigma_B^2 &= \alpha^2(\sigma_{\hat{P}_B^A})^2 + (1 - \alpha)^2 \cdot (\sigma_{\hat{P}_B^B})^2 + 2\alpha(1 - \alpha) \cdot \sigma_{\hat{P}_B^A} \\ &\quad \cdot \sigma_{\hat{P}_B^B} \cdot \rho(\hat{P}_B^A, \hat{P}_B^B).\end{aligned}\tag{9B}$$

The corresponding expressions for the B resident consist of exactly the same factors, but the consumption bundle of B residents must be substituted for  $\alpha$ .

Only the variances of the prices in the currency in which the investor chooses to invest need be taken into consideration to measure the variance of the real rate of return on an investment. Accordingly, both A investors and B investors need consider only the variances of the prices in the A (or B) currency to estimate the total variance of an investment in the currency of country A (or B). In this sense, the inflation risks of the two currencies are still symmetrical. But there is a difference now in that the consumption bundle enters as a determinant of the total risk.<sup>1</sup> Residents of the two countries may face different risks on the same investment if they have different consumption bundles. This can not be a cause of exchange risk, however, because an increase in the variance of a particular price affects the riskiness of an investment in the same way for investors in both countries.

There is a second circumstance that may cause the riskiness of an investment in a currency to differ for A and B residents—when the variance of the rate of change in the price of a particular good is different in the two countries. Heckerman's case above was an extreme example. The price of one good was known in country A, while the price of the other good was known in country B. The price of the good produced abroad fluctuated with the exchange rate in both countries.

If good A is produced in country A and good B in country B, the Heckerman case can be described in the following way:

<i>For A residents</i>	<i>For B residents</i>	
$\sigma_A^2 = (1 - \alpha)^2 \cdot \sigma_X^2$	$\sigma_A^2 = (1 - \beta)^2 \cdot \sigma_X^2$	
$\sigma_B^2 = \alpha^2 \sigma_X^2$	$\sigma_B^2 = \beta^2 \sigma_X^2$	(10)

<sup>1</sup> One can question the validity of distinguishing between the consumption bundles of inhabitants in different countries. Of course, it is the risk faced by individuals that differs because of different bundles even though they invest in the same currency. However, if consumption bundles depend systematically on residency, risk can be said to depend on residency.

where  $\sigma_x^2$  is the variance of the rate of change in the exchange rate and  $\beta$  is the share of good A in the consumption bundle of B residents.

All investors face identical risks when consumption bundles are the same ( $\alpha = \beta$ ), but a case for exchange risk can now be made when consumption is biased toward domestically produced goods ( $\alpha > \beta$ ). An increase in the variance of the exchange rate will then increase the variance of the foreign investment more for the domestic resident than for the foreign resident.

There is, however, no theoretically necessary relationship between the terms of trade and the exchange rate. The price of the foreign good may not fluctuate with the exchange rate. Demand and supply elasticities in the two countries determine the short-run relationship between the terms of trade and the exchange rate. Therefore, to determine the riskiness of investments in different currencies, it makes more sense to distinguish between price-making and price-taking countries, although this is a very difficult distinction to make. Uncertainty about the price of a commodity depends on uncertainty about productivity and wage developments in the price-making country, while the variance of the exchange rate has to be added to determine the variance of the price of the same commodity in the price-taking country. The higher the variance of the exchange rate, the higher is the risk of holding the currency of the price-taking country for planned purchases of a certain product. The variance of this share of a person's wealth can be reduced by investing in the currency of the price-making country.

A general case for exchange risk, i.e., an additional risk on foreign-currency investments, can be made only if (1) countries in general are price makers on domestically produced goods, that is, the prices of domestically produced goods are set primarily by domestic demand and supply conditions, and (2) inhabitants in all countries are biased toward consumption of domestically produced goods. Going back to the expressions for the risks of different investments (9B), condition (1) implies that  $(\sigma_{\hat{P}^A})^2 < (\sigma_{\hat{P}^B})^2$  and  $(\sigma_{\hat{P}^A})^2 > (\sigma_{\hat{P}^B})^2$ , and condition (2) implies that  $\alpha > \beta$ . Leaving the correlations aside, (1) and (2) imply that  $\sigma_A^2$  for A residents  $< \sigma_A^2$  for B residents, and  $\sigma_B^2$  for A residents  $> \sigma_B^2$  for B residents.

Finally, let us compare the results of this analysis with Kouri's (1976a) treatment of exchange risk and inflation risk. He studies the risks associated with international investments under the assumption that there is perfect commodity arbitrage for two goods, one produced domestically and one produced abroad. The price of the good produced abroad fluctuates in both countries with the exchange rate. In Kouri's terminology, terms-of-trade fluctuations cause exchange risk, while inflation risk

on an investment in a certain country depends on fluctuations in the price of the good produced in that country. Thus the inflation risk and the exchange risk of an investment depend on the consumption bundle of the investor.

The basic difference between Kouri's results and the results here proceed from the definition of PPP. In Kouri's analysis, relative-price changes cause deviations from PPP because each country's price level is defined in terms of the good produced in that country. With this terminology, inflation *causes* a relative-price movement between domestic and foreign goods. Clearly, inflation risk will then depend on the share of the domestic good in the consumption bundle. Similarly, exchange risk depends on the consumption bundle because exchange-rate fluctuations cause terms-of-trade fluctuations. The latter show up as deviations from PPP when price levels are defined in terms of domestically produced goods. As we have seen, such relative-price changes need not make foreign investments particularly risky. Kouri's exchange risk is therefore not a risk associated with a foreign investment except under conditions (1) and (2) above.

It seems desirable to distinguish between risks that arise from uncertainty about nominal variables and risks that arise from uncertainty about real variables. Price levels and exchange rates are nominal variables. The terminology used in this study distinguishes between inflation risk arising from uncertainty about the rate of change of price levels in terms of *all* goods and exchange risk arising from uncertainty about exchange-rate changes that are not reflected in price levels. There is a relative-price risk when exchange-rate fluctuations cause terms-of-trade changes. The effects of relative-price risk depend on an investor's consumption bundle.



## 4 RISKS AND EXCHANGE-RATE REGIMES

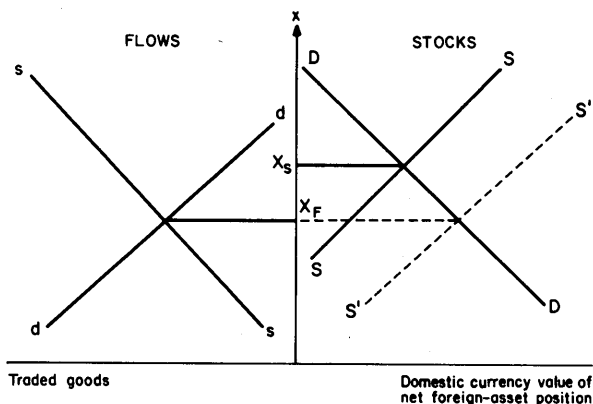
In this chapter, we look first at some recently developed models of exchange-rate determination under a flexible-exchange-rate regime and find that all the risks discussed in Chapter 3 can be reconciled with an internally consistent model. In sections 4.2 and 4.3, the theoretical grounds are set forth for identifying the kinds and magnitudes of risk associated with different exchange-rate regimes. Empirical data on risks under actual exchange-rate regimes are studied in section 4.4.

### 4.1 *Exchange-Rate Determination, Prices, and Risks under a Flexible Regime*

Black (1976) and Kouri (1976b) use a flexible-exchange-rate model in which the exchange rate at each instant is determined by a stock-equilibrium condition, and the long-run exchange rate is determined by a flow-equilibrium condition. Two goods are produced domestically, a traded good, for which commodity arbitrage is perfect, and a nontraded good. In the long-run flow equilibrium, the relative price of these two goods is determined by tastes and technology. However, in the short run, exchange-rate fluctuations change the relative price of the traded and nontraded goods, assuming the price of the traded good to be determined in the world market. A depreciation of the domestic currency raises the domestic price of the traded good. The supply (*ss*) of the traded good increases and the demand (*dd*) decreases (see Fig. 1). There will be a current-account surplus, implying that the stock of foreign assets increases over time (*SS* shifts to the right in the right-hand figure).

Turning to the stock side, the supply of foreign assets—counted as the *number* of assets—is given at each point in time and changes only with current-account imbalances. The domestic-currency value of the foreign assets increases with a depreciation of the domestic currency. This gives a supply curve (*SS*) at a point in time. The demand for foreign assets (*DD*) is determined by relative interest rates, risks, and anticipations about the future exchange rate given the current exchange rate. With these variables constant, the demand for foreign assets decreases when the exchange rate depreciates, because the foreign assets become more expensive the more expensive is foreign exchange. In the short run, the exchange rate is determined by the stock-equilibrium condition that domestic residents must be willing to hold the existing supply of foreign assets. If

FIGURE 1  
DETERMINATION OF THE EXCHANGE RATE IN THE SHORT RUN AND THE LONG RUN



they are not willing, the domestic currency appreciates. One such stock equilibrium is  $X_S$  in Figure 1. At this exchange rate, there is a surplus on current account, increasing the supply of foreign assets and shifting  $SS$  to  $S'S'$  until  $X_S = X_F$ , where there is flow equilibrium. In this flow equilibrium, PPP holds again. The exchange rate has not influenced the equilibrium relative price between traded and nontraded goods.

In this model, it is easy to see why there can be random fluctuations of the exchange rate around PPP. As soon as one of the nominal interest rates changes and the anticipated future exchange rate changes, the demand curve ( $DD$ ) will shift and with it the instantaneous exchange rate. The relative price of traded and nontraded goods changes with the exchange rate. As soon as there are deviations from PPP, however, there is pressure on the exchange rate to return to PPP. Thus, there can be inflation risks in this model if there is uncertainty about domestic and foreign general price levels. A general inflation in a country, which raises the prices of traded as well as nontraded goods, forces the equilibrium exchange rate to depreciate with the inflation. To the extent that there is uncertainty about the future exchange rate, investors also face exchange risk for the share of consumption that consists of nontraded goods. This uncertainty arises from uncertainty about all factors affecting the stock demand curve, especially nominal interest rates and exchange-rate expectations in the near future.

It is clear that in this model exchange risk is particularly pertinent to short-term investments in foreign-currency assets. As there will always be pressure on the exchange rate to go back to PPP, there is a limit to

the variability of the relative price of traded and nontraded goods. Therefore, the longer the time horizon the less the investor need take exchange risk into account. Instead, for long time horizons the most important factors in his portfolio decision will be anticipations about relative-price levels and the variance of inflation rates.

Branson (1977) has also used the basic feature of this model of exchange-rate determination, but instead of traded and nontraded goods, Branson's model has two countries each producing a commodity. Both goods are traded in perfectly competitive international markets, which is to say that PPP holds in the terminology used here. (In Branson's terminology, PPP need not hold at all times, because he has defined price levels in terms of the domestically produced good.)<sup>1</sup>

The stock side of Branson's model is like Black's model, but the flow side is slightly different. Each country is a price maker for its domestically produced good so that a depreciation of its currency raises the price of the imported good. This causes a demand shift toward the domestic good in the depreciating country. In the appreciating country, the import falls in price, causing a demand shift toward the same good. The current account changes in the same way as in Black's model, changing the supply of foreign assets and driving the exchange rate and the relative price back toward their original levels.

Just as in Black's model, there is uncertainty about the stock-determined exchange rate if there is uncertainty about nominal interest rates, the future exchange rate, and other factors determining the stock demand for assets denominated in the foreign currency. The uncertainty about the exchange rate causes the relative-price risk discussed in section 3.5. This uncertainty is mainly a risk on short-term investments. In the long run, inflation risk dominates once more.

The assumption that the producing country is the price maker is not essential to Branson's model. The producing country could have been the price taker, so that the domestic price of the export would rise with a depreciation. The supply of the exported good would then increase after a depreciation and create the necessary adjustment of the current account.

Other versions of the same model can be set up. Assume, for example, that there is perfect commodity arbitrage for all products and that we cannot define any price-making or price-taking countries, i.e., no relative-price changes occur and PPP holds at all times for commodity prices. The current-account adjustments to exchange-rate changes must now be brought about by changes in the *factoral* terms of trade. This can occur when nominal wages are rigid. A fall in the nominal interest rate at certain

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<sup>1</sup> Compare the discussion on page 24.

expectations increases the demand for foreign assets; the exchange rate depreciates, with the result that prices increase on *all* goods in the domestic currency. With rigid wages, domestic profits rise, so that the supply of domestic goods increases and creates a current-account surplus. In this case, uncertainty about the future exchange rate causes only inflation risk for investments in any currency.

Finally, exchange-rate fluctuations due to shifts in the demand for foreign assets may simply cause deviations from PPP. This will be the case when the domestic price level is determined primarily by domestic factors, the foreign price level is determined primarily by foreign factors, and commodity arbitrage takes time. A depreciation of the domestic exchange rate increases domestic producers' supply to the foreign markets and decreases foreign producers' supply to the domestic market. Again, the current account goes into surplus, increasing the supply of foreign assets. The exchange rate starts to appreciate toward its original PPP level. In this case, uncertainty about the exchange rate will produce pure exchange risk in the short run, while inflation risk will dominate in the long run. The magnitude of exchange risk depends on the efficiency of international commodity markets, i.e., the distance between the commodity points.

This outline of the theory of exchange-rate determination under flexible rates shows that all the risks that have been discussed can be generated by flexible exchange rates. Which adjustment pattern is the most common, that is, which price variable follows or does not follow fluctuations of the exchange rate, can be determined empirically. The only conclusion that can be reached at this point is that the longer the time horizon the less important are exchange and relative-price risks. Over the long run, the variance of the inflation rate determines the riskiness of investing in a certain currency, because there are limits to the extent that relative prices can change as a result of exchange-rate fluctuations and the extent that the exchange rate can deviate from PPP. The contribution of these factors to the variance of the rate of return on a yearly basis must therefore decrease as the time horizon lengthens. (Compare section 2.5.)

#### 4.2 *Risks under Fixed and Flexible Rates*

With a fixed exchange rate, the band limits the fluctuations of the exchange rate in response to changes in interest rates, the anticipated future exchange rate, and other factors determining the DD curve in Figure 1. Fluctuations in the relative price of traded and nontraded goods, domestic and foreign goods, and the factorial terms of trade and deviations from PPP are then also limited by the band. It does *not* follow, however,

that there is less exchange and relative-price risk under a fixed-exchange-rate regime. Two conditions must be met for flexible rates to cause more risk than fixed rates. A *necessary* condition is that the variance of the flexible rate be larger than the variance of the fixed rate within its band. A *sufficient* condition is that the "commodity points" and the limit on relative prices be wider apart than the band of the fixed exchange rate. Otherwise, the variance of a flexible exchange rate will correspond to the variance of at least one inflation rate.

Disturbances causing deviations from PPP and relative-price changes may, of course, originate in commodity markets as well as in capital markets. For example, deviations from PPP may be caused by price fluctuations at a fixed exchange rate. However, such fluctuations do not cause any exchange risk, because there are no corresponding exchange-rate fluctuations (see section 3.3).

The degree of uncertainty about the exchange rate in the short run under a flexible regime, compared with that under a fixed regime, depends very much on whether arbitrageurs stabilize or destabilize the flexible exchange rate. Fluctuations in the exchange rate arise from shifts in all the variables that determine the demand for foreign assets, the most important of which are nominal interest rates and exchange-rate expectations. The more these variables fluctuate, the more likely it is that the exchange rate will fluctuate. However, if the future flow-equilibrium, or long-run, exchange rate is easily predictable, arbitrage will probably stabilize the exchange rate. Since the long-run equilibrium rate is determined by PPP, it is crucial that arbitrageurs get the information necessary to predict future relative-price levels. The higher the uncertainty about the future inflation rate in a country, the more difficult it is to predict the future equilibrium exchange rate and the less likely it is that arbitrage will be stabilizing and thereby lower the exchange risk faced by investors under a flexible regime. This reasoning leads to the conclusion that *inflation risk is not independent of exchange risk or relative-price risk*. We shall see below that announcements of monetary-growth targets may reduce the variance of the inflation rate. Thus, the risks depend very much on the behavior of central banks and the predictability of their behavior.

The only difference that can be argued on theoretical grounds between a fixed-exchange-rate regime and a flexible-exchange-rate regime is the independence of the inflation rates of the countries concerned. With fixed rates between two currencies, the inflation rates must be identical in the long run in order to maintain flow equilibrium. The correlation between the inflation rates is therefore close to 1 by necessity, while under a flexible regime the correlation can be anything from  $-1$  to  $+1$ .

### 4.3 *Risks under the Adjustable Peg*

In Chapter 2, we saw that under an adjustable-peg regime there is always some probability of a large abrupt adjustment of the exchange rate. Almost by definition, arbitrageurs cannot perform a stabilizing or dampening role under this regime. Consequently, the variance of the anticipated change of the exchange rate must be high during periods of high uncertainty about the peg. Exchange risk will also be high unless relative-price levels rapidly adjust as much as the exchange rate. The relative-price risk will likewise be considerable if the terms of trade change with the exchange rate. Again, we must look at the empirical evidence to evaluate the importance of the different kinds of risk, but we can say this much in theory: During periods of high uncertainty about the peg, exchange risk, the relative-price risk, *or* the variance of at least one inflation rate must be relatively high. The difference between adjustable and flexible regimes is that with adjustable exchange rates short-run riskiness of one kind or another necessarily follows from the behavior of the monetary authorities, while with flexible exchange rates the monetary authorities can help to lower risks. Over the long run, the adjustable peg becomes similar to a flexible regime, since in both cases inflation rates can be regarded as independent and PPP holds in the long run under any regime.

This theoretical and ad hoc discussion does not give much ground for claiming that one regime causes more risk of a particular kind than another. We must therefore study the empirical evidence on the variables that caused risks during the recent period of changing exchange-rate regimes.

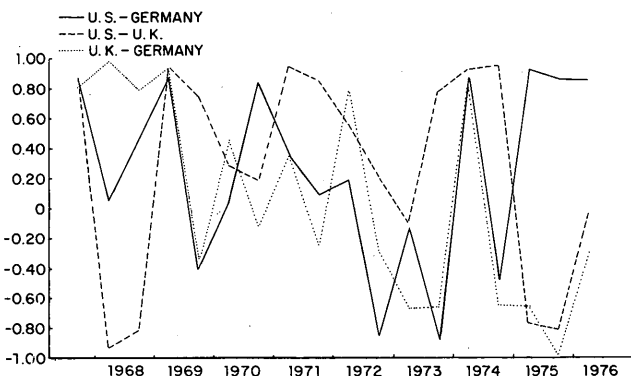
### 4.4 *Empirical Evidence on Risks under Different Exchange-Rate Regimes*

To assess the relative magnitudes of the risks under different exchange-rate systems, we look at data for the period 1967 to 1976. This was a transitional period during which the international monetary system went from a regime of virtually fixed exchange rates to one of flexible rates for many currencies, via a period of adjustable exchange rates during the late 1960s and early 1970s. Unfortunately, it is impossible to isolate the effects on risks caused by changing exchange-rate regimes. When comparing the different regimes, it must be borne in mind that the changes in the monetary system did not follow from a simple decision to move toward more flexible rates. Rather, they occurred in response to higher and more divergent inflation rates during the late 1960s.

We start by looking at variances of inflation rates and the correlation between inflation rates.<sup>2</sup> Figure 2 shows the semiannual correlations between the inflation rates in the United States, the United Kingdom, and Germany. There seems to be a downward tendency until 1972-73. Then the dollar-mark correlation moves up close to 1, falls back during 1974, and goes up again in 1975. The correlations between the pound and the other two currencies fall very low during the last part of 1974 and 1975. These short-term correlations seem to fluctuate a great deal and do not necessarily fall because of flexible exchange rates. The behavior of the central banks is crucial.

FIGURE 2

SEMIANNUAL INFLATION CORRELATIONS FOR THE UNITED STATES, THE UNITED KINGDOM, AND GERMANY, 1967-76



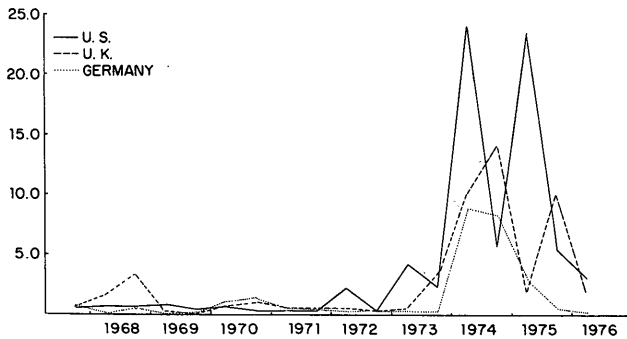
NOTE: For each country, a semiannual observation consists of 6 quarterly inflation rates, starting at the beginning of each month of the semiannual period.

Figure 3 shows semiannual variances of inflation rates for the three currencies. Until 1973, all the variances were low, with only occasional increases. Since 1973, they have become higher and more divergent. The timing coincides with the shift toward flexible exchange rates. However, during 1975 the German inflation variance fell back to a very low level. This development may reflect the German policy of stating the monetary-growth goal in advance and then sticking to it. It is evidence that inflation risks may be subject to control by monetary authorities and that high and divergent inflation risks do not necessarily follow from flexible exchange rates.

<sup>2</sup> Parts of the arguments and the diagrams below are adapted from Wihlborg (1978a).

FIGURE 3

SEMIANNUAL VARIANCES OF INFLATION RATES FOR THE UNITED STATES,  
THE UNITED KINGDOM, AND GERMANY, 1967-76



NOTE: For each country, a semiannual observation consists of 6 quarterly inflation rates, starting at the beginning of each month of the semiannual period.

Exchange risk was defined as the variance of the rate of change of deviations from PPP, which depends on the degree of integration of commodity markets between countries. By studying empirically the effectiveness of commodity arbitrage, it should be possible to determine if the "commodity points" are farther apart under flexible rates than the bands of a fixed exchange rate. If they are, exchange risk becomes higher with flexible rates whenever exchange rates fluctuate more than would be allowed under fixed rates. Unfortunately, the estimates of the changes in deviations from PPP in the studies described below do not distinguish between the degrees of commodity-arbitrage efficiency for different products, so that they unavoidably include deviations due to changing relative prices between traded and nontraded goods.

Yeager (1966) refers to evidence on PPP between the United States and Canada during a period when the exchange rate between the two countries was allowed to fluctuate. The study shows that the monthly average of the fluctuating exchange rate was within 3.5 per cent of PPP for wholesale prices in 96 per cent of the months from October 1950 through June 1957. For retail prices, the corresponding figure was 83 per cent of the months. While these monthly data are rather impressive, the fluctuations are wider than the band within which a pegged exchange rate is allowed to fluctuate and the data cover only the United States and Canada.

Dunn (1970) studied how well the "law of one price" held for individual commodities in Canada and found that commodity arbitrage is highly inefficient over six-month periods. The commodities studied by Dunn were few, however.



Figure 4 shows annual percentage rates of change in the deviations from wholesale-price PPP over quarters and years for the United States, West Germany, and the United Kingdom. It is obvious that the changes in the deviations have been much larger over quarters than over years. Furthermore, the fluctuations of the quarterly changes have been much larger during the flexible-rate period than they were during the fixed-rate period. Points of adjustment of pegged rates do show up clearly, however. The yearly deviations have not changed substantially, so that the variance of the deviations from PPP have mostly hit short-term investments. Nevertheless, the yearly changes are much larger than a band around a fixed rate, implying that exchange risk is also substantial for one-year investments in foreign currencies. All this assumes that price indices accurately capture actual changes in purchasing power. But since relative-price changes affect price indices and listed prices do not take into account rebates that might result from exchange-rate changes, price indices probably exaggerate deviations from PPP. It is impossible to determine whether imperfections in the data account for a proportion of the deviations large enough for us to say that PPP is a reasonable approximation over one-year periods.

Unfortunately, with the exception of Germany, the data do not cover any period with both flexible exchange rates and low inflation variances. To test the hypothesis that exchange risk derives from unpredictable inflation rates, we need a period during which at least two countries' inflation rates have been stable.

Figure 5 shows semiannual variances of the changes in deviations from PPP between the same three currencies as above. For comparison with the deviations from PPP, the figure also shows the variances of the rates of change of exchange rates. The two variances move very closely for each currency, indicating that short-run fluctuations of the exchange rate cause deviations from PPP of about the same magnitude. This means that, for short-term investments, exchange risk must be a major concern whenever there is uncertainty about the exchange rate.

It is also noteworthy that both sets of variances were very low during the period of fixed exchange rates. This implies that exchange-rate fluctuations are a much more important source of deviation from PPP than different inflation rates under a fixed exchange rate. The variance of the changes of deviations from PPP can therefore be used as a proxy for exchange risk under all regimes without exaggerating the exchange risk under a fixed regime.

Relative-price risk is the final risk for which the empirical evidence should be examined. Relative-price risk is the risk on an investment in a currency in which the price of a product to be consumed in the future

FIGURE 4

ANNUAL PERCENTAGE RATES OF CHANGE IN THE DEVIATION FROM WHOSESALE-PRICE PPP FOR THE UNITED STATES, THE UNITED KINGDOM, AND GERMANY OVER QUARTERS AND YEARS, 1967-76

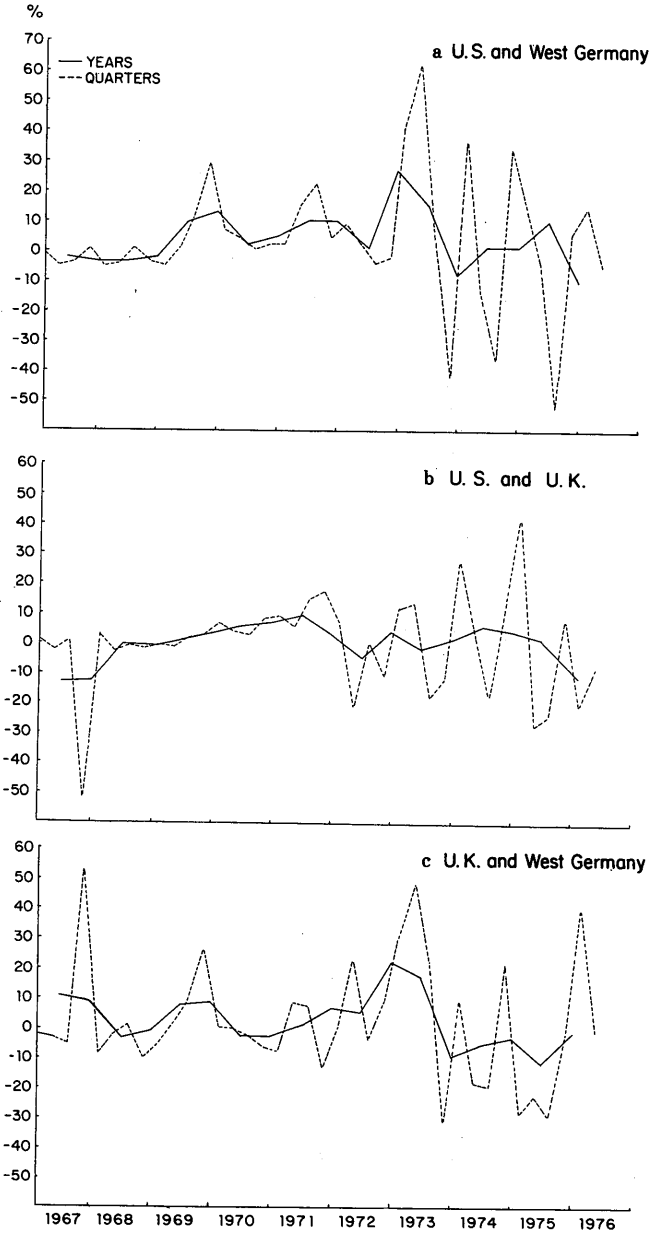
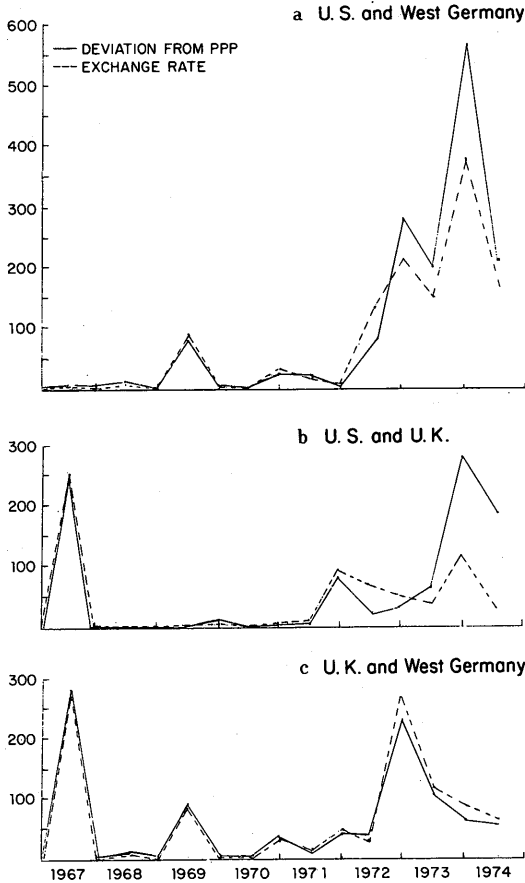


FIGURE 5

SEMIANNUAL VARIANCES OF RATES OF CHANGE IN THE DEVIATION FROM PPP AND THE EXCHANGE RATE FOR THE UNITED STATES, THE UNITED KINGDOM, AND GERMANY, 1967-74



NOTE: A semiannual observation consists of 6 quarterly observations of rates of change, starting at the beginning of each month of the semiannual period.

fluctuates with the exchange rate. It will occur if one country is a price maker, that is, if the price of the commodity is set primarily by supply and demand conditions in that country. Commodity arbitrage must work very well, so that the prices of the product in other currencies follow the exchange rates.

If residents of all countries have a strong preference for domestically produced goods *and* if prices of imported goods fluctuate with the ex-

change rate, then relative-price risk can be treated like exchange risk. The first condition is very likely to hold. What we need to study, therefore, is whether exchange-rate fluctuations are correlated with the terms of trade.

One way to test for the correlation is to compare monthly data on the exchange rate between Canadian and U.S. dollars with monthly data on the Canadian terms of trade (export price index/import price index). It is an imperfect test, but the United States plays such an important role in Canada's trade that any relative-price effect of fluctuations of the Canada/U.S. exchange rate should show up in the Canadian terms of trade.

An examination of monthly data from 1950 through 1973 does not reveal any clear relationship, however. During 61 months, the terms of trade improved with a depreciating exchange rate or deteriorated with an appreciating exchange rate. During 75 months, the opposite relationship held. Neither the terms of trade nor the exchange rate changed during 34 months, and the exchange rate changed without any terms-of-trade movement during 64 months. (No change is defined as less than 0.1 per cent change.) Nevertheless, there were periods with very clear relationships. From May 1951 to August 1952, the Canadian dollar depreciated sharply while the terms of trade deteriorated significantly. On the other hand, from October 1970 to February 1971, the Canadian dollar appreciated while the terms of trade deteriorated.

A recent study by Isard (1977), however, indicates a very strong relationship between relative prices for some imported goods or commodity groups and the exchange rate. Isard compares monthly time series of U.S. wholesale prices and German export prices in dollars for a variety of industries over the 1968-75 period. The variance of the relative prices for apparel and for paper products is almost entirely explained by the mark/dollar exchange rate. This indicates strong product differentiation and price making in the domestic markets and it also indicates well-functioning commodity arbitrage. Otherwise, export prices would not follow the exchange rate. For other commodity groups, Isard studies the behavior of the same relative price in eight-month periods during which the exchange rate was fairly stable. For 5 of the 9 commodity groups, the exchange rate explains a large part of the variation of the relative price.

Isard also disaggregates further into selected categories of machinery goods and confirms the result that exchange-rate changes lead to substantial and persistent changes in relative common-currency prices.

Finally, Isard compares unit values of U.S. exports with unit values of U.S. imports from Canada, Germany, and Japan at a very disaggregated level (tires, wallpaper, steel bars, soap). The unit-value data fluctuate

erratically, but in regressions the ratios of German and Japanese dollar prices to U.S. dollar prices are significantly and positively dependent on the dollar prices of the mark and the yen, respectively, for almost all the commodity groups. The same finding does not hold for Canada, however, either because the exchange rate fluctuated much less or because American and Canadian products are less differentiated.

In conclusion, there are strong indications that relative prices change with exchange-rate changes for many commodity groups. This indicates that, to the extent that these commodities are a part of an investor's planned consumption bundle, he should invest in the producing country's currency in order to protect himself against fluctuations of domestic-currency prices. The data do not cover enough commodity groups, however, to justify a general conclusion that foreign-currency investments are riskier than domestic ones because of uncertainty about the exchange rate. Furthermore, there are certainly many products produced domestically whose prices are determined in foreign markets or in specific currencies. Investors planning to purchase such products (raw materials, for example) with the domestic currency can avoid some risk by investing in the currency in which the price of the product is determined.

#### *4.5 Summary of Theoretical and Empirical Results Regarding Currency Risks under Different Exchange-Rate Regimes*

The fluctuations of an exchange rate between two currencies fall into three categories. The fluctuations correspond either to changes in one of the two price levels or to changes in the deviation from PPP. Without deviations from PPP, there is no exchange risk specific to investments in foreign currencies. Instead, there are risks associated with investing in particular currencies, independent of the investor's habitat.

Exchange risk decreases in importance as the time horizon of a foreign-currency investment lengthens because deviations from PPP create economic incentives for commodity arbitrage or demand shifts between non-traded and traded goods until PPP is restored. Thus, for investments over several years exchange risk is likely to be unimportant, while for very-short-term investments exchange risk may be considerable under any regime.

The nature of inflation risk under a flexible-exchange-rate regime is different from that under a fixed-rate regime because the inflation rates of two countries can be very different. Inflation variances in the two countries may therefore be very different and the correlation between the inflation rates low. An adjustable-peg regime also leaves room for dif-

ferent inflation rates and, for long-term investments, must be considered similar to a flexible-rate regime.

Inflation variances have been high and different since the period of flexible rates began, and correlations between inflation rates have decreased relative to the fixed-rate period. High inflation risk need not necessarily result, however. That it can perhaps be controlled by the monetary authorities is shown by Germany, where the central bank has announced future monetary growth rates and approximately achieved them.

Exchange risk has been considerable during the same period. Exchange rates have fluctuated widely, and commodity arbitrage has been insufficient to ensure PPP even over periods up to a year. Theoretically, this high exchange risk is not a necessary consequence of flexible rates. It arises from ineffective commodity arbitrage and uncertainty about exchange rates. The uncertainty is probably partly due to the same source as high inflation risk—the unpredictability of the behavior of the monetary authorities. If the monetary authorities announced inflation and monetary-growth targets, equilibrium exchange rates could be foreseen more clearly. Arbitrage would then be more likely to be stabilizing than it has been. Unless the predictability of both equilibrium exchange rates and the behavior of the monetary authorities increases, exchange risk will continue to be very high for short-term investments under a flexible-rate regime.

An adjustable-peg regime is like a fixed-rate regime during periods of relative certainty about the peg. But if there is uncertainty about the peg and the timing of adjustments, there is likely to be considerable exchange risk, because commodity arbitrage cannot ensure PPP in the short run. The purpose of adjustment is often to offset deviations from PPP that have already occurred. To succeed, an adjustment must therefore imply a considerable rate of change in the deviation from PPP.

Finally, exchange-rate fluctuations are likely to produce uncertainty about the relative prices of certain commodities. For products that are differentiated between producers in different countries, foreign-currency prices seem to fluctuate with the exchange rate. The more that domestic products dominate consumption bundles, the greater the risk of investment in foreign-currency assets relative to the risk of investment in domestic assets. Investors should invest in the currency of the country that is the price maker of the product to be consumed if they wish to hedge against the risk of changes in the terms of trade as a result of exchange-rate fluctuations.

## 5 PORTFOLIO ALLOCATION AND THE FUNCTIONING OF INTERNATIONAL FINANCIAL MARKETS

### 5.1 *Risks and Portfolio Behavior*

The effects of risks on the choice investors make between assets denominated in different currencies are examined here by means of a simple mean-variance model. This is a necessary first step before drawing conclusions regarding the effects of different kinds of risk on the functioning of capital markets, on trade flows, and on the effectiveness of monetary policy. The model and the derivations are shown in the Appendix and are summarized here.

Investors are assumed to optimize their expected utility at the end of an investment period. There are two countries and two assets with uncertain real rates of return. Assuming that the anticipated real rates of return and the variables that affect them are normally distributed, the expected utility will be a positive function of the expected real rate of return on the portfolio and a negative function of the variance of this real rate of return.

The main weakness of the two-asset model is that we have to limit the study to the allocation between domestic and foreign assets in general. In reality, an investor has a choice between many foreign currencies with different properties. The rate of change in the deviation from PPP between the domestic currency and a foreign currency may be correlated with the rate of change in the deviation from PPP between the domestic currency and another foreign currency. To study the allocation among many currencies, a multi-asset model is needed. Nevertheless, this two-country model produces some interesting qualitative results regarding the effects of changing risk levels and correlations.

Using a utility function with the property of constant absolute risk aversion,<sup>1</sup> the following results are derived in the Appendix:

*The condition for a positive net wealth position in a foreign currency.* To induce a positive net wealth position in a foreign currency, the expected foreign rate of return must compensate for the variance of the foreign rate of return in excess of the covariance between the domestic and the foreign rates of return. Exchange risk, as a risk specific to foreign investments, drives a wedge between the two asset markets in the sense that there must be some compensation for an investor to take a positive net wealth position in a foreign currency.

*Changes in risks and portfolio choice.* The desired proportion of an

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<sup>1</sup> The absolute value of the risk premium is independent of income.

asset increases with the expected rate of return. The effect of an increase in the domestic risk on the desired proportion of the domestic-currency asset depends on initial holdings. If there is no correlation between the real rates of return of the two assets (the inflation rates of the two countries), an increase in the domestic inflation risk leads to decreased demand for the domestic-currency asset if initial holdings are positive (if the investor is a net lender in the domestic currency) but to increased demand if initial holdings are negative (if he is a net borrower). A net lender in the domestic currency will decrease his lending in that currency when its riskiness increases, while a net borrower will repay some of his borrowing in that currency.

When the correlation is not zero but positive, a finite amount of net borrowing is necessary to obtain the result that borrowing in the risky currency will decrease with higher risk. However, as a reasonable approximation, we state that if there is risk aversion on both the lending and the borrowing sides of a market, both sides tend to get out of the currency in which inflation risk is increasing. Both the supply of and the demand for an asset decrease with higher inflation risk in the currency in which it is denominated.

Applied to a rise in exchange risk, the result implies that borrowers as well as lenders reduce their activity in foreign currencies.

*Changes in the correlation between inflation rates and portfolio choice.* When deviations from PPP are independent of inflation rates, investors need consider only the correlation between the inflation rates of the two currencies in order to make their portfolio choice. This is the one variable that is affected by the type of exchange-rate regime (see Chapter 2). It is shown in the Appendix that a rise in the correlation between the real rates of return in the two countries induces investors to increase their share of the asset that already dominates their portfolio. Conversely, a decrease in the correlation induces investors to hold a smaller share of the dominating asset. The implication of this result is that the incentive for investors to diversify increases with a lower correlation between inflation rates.

Applied to exchange-rate regimes and the conduct of monetary policies, the implication is that, when inflation rates diverge, investors tend to increase their holdings of the currency of which they held the smaller amount initially. If the portfolios of investors in all countries were dominated by domestic currencies during the fixed-exchange-rate regime, we would expect to find that investors increased their holdings of foreign currencies after inflation rates began to diverge during the 1970s. On the other hand, if dollars dominated their portfolios during the fixed-exchange-rate regime, we would expect to find that investors have diversified away from dollars.



*Risks and elasticities.* A measure of market integration for assets denominated in different currencies is the size of the portfolio shift in response to a change in the relative expected rate of return (see Wihlborg, 1978a). By "portfolio shift" is meant the change in the desired proportions of the two assets. Thus, we want to find an expression for the elasticity of desired proportions with respect to the difference between rates of interest. In the Appendix, it is shown that this elasticity decreases at all initial proportions with (a) a higher variance of the exchange rate, whatever the source, and therefore with (b) a higher inflation risk in either of the currencies (for exceptions, see the Appendix); with (c) a higher exchange risk; and with (d) a decreasing correlation between the two inflation rates. Zero elasticity implies that the two assets are not considered to be substitutes at all, while infinite elasticity implies that the two assets are perfect substitutes. In the latter case, investors will hold only the asset with the highest expected rate of return.

Applied to exchange-rate regimes, the conclusion is that substitutability between assets denominated in different currencies decreases with a divergence of inflation rates and higher risks of any kind. Thus, higher risk or a lower correlation between inflation rates provides some "insulation" of the markets for financial assets denominated in different currencies.

## 5.2 *Risks and the Functioning of International Capital Markets*

The greatly increased exchange risk since the period of flexible rates began in the 1970s must have affected international capital markets. We would expect short-term capital flows to have become less interest-rate sensitive. This follows from the result that the elasticity of desired proportions of assets denominated in different currencies becomes lower as risks become higher.

The same conclusion holds for the interest-rate sensitivity of long-term capital flows, but for a different reason. Exchange risk is largely irrelevant for long-term investments, but the high inflation risk observed in recent years should have lowered the elasticity of desired proportions of long-term investments in different currencies with respect to interest-rate differentials. In addition, the correlation between the inflation rates has decreased, lowering the elasticity still further.

The results described in the previous section were derived under the assumption of immediate portfolio adjustments in response to changes in incentives. However, some of the results enable us to draw conclusions about how risks affect the speed with which adjustments take place.

Speed of adjustment is probably of major importance for the efficiency of capital markets.

Another important factor is the size of a market for a certain asset. The liquidity of an asset depends on how long an investor must search in order to sell at the market value. And the more participants there are in a market, the less volatile will be price movements. The most important conclusion of the mean-variance model in this context is that both lenders and borrowers tend to get out of a relatively risky asset. Thus, if uncertainty increases about a country's inflation rate, borrowers tend to issue, and investors tend to demand, fewer bonds denominated in its currency. The market becomes thinner for assets denominated in the high-risk currency, with possible consequences for the liquidity of the assets and the volatility of price movements. For a big country with well-developed capital markets this effect may be negligible, but for countries with less developed capital markets it could be quite important.

High exchange risk may also thin out certain markets. Since exchange risk is specific to foreign investments, the higher exchange risk cannot affect the market for assets of a specific currency. Instead, it is the foreign-exchange markets that become thinned out by high exchange risk, as fewer participants demand or wish to supply foreign exchange for purposes of short-term arbitrage. Again, for currencies with big, well-developed markets this is unimportant. But for countries with less developed capital markets and relatively thin foreign-exchange markets to begin with, it may be quite serious. The higher exchange risk becomes self-perpetuating because the thinning out contributes to more volatile exchange-rate movements: Fewer arbitrageurs will be there to stabilize a flexible exchange rate.

Increased uncertainty about the rate of return on an asset also increases the transactions cost of buying and selling the asset, because dealers in the market must take higher risks in their daily operations (see, e.g., Malkiel, 1966). Increased inflation risk for a currency should therefore increase the cost of buying and selling assets denominated in that currency. The higher transactions costs create a wider bid-ask spread within which the market price may fluctuate without creating incentives to arbitrage. Similarly, higher exchange risk may increase transactions costs in the foreign-exchange markets. Aliber (1976) provides some empirical evidence that bid-ask spreads for many currencies have widened during the period of flexible exchange rates.

## 6 INSTITUTIONAL ADJUSTMENTS TO HIGHER RISKS

### 6.1 *Multi-Currency Bonds and Roll-Over Credits*

Throughout the analysis, nominal interest rates have been assumed to be known on the day of purchase. This is a crucial assumption. We saw in the analysis of risks that there would be no currency risks at all in a PPP world if the nominal rate of return on bonds varied with the inflation rate. But, even then, uncertainty about deviations from PPP would cause exchange risk for short-term investments.

At present, a very large proportion of the bonds issued in international capital markets, whether short-term or long-term, have fixed nominal rates of return. Two recent innovations, however, can be interpreted as the institutional response to more independent inflation rates and high inflation risk, respectively: multi-currency bonds and roll-over credits. Multi-currency bonds are bonds of rather long maturities that are denominated in a basket of currencies. Roll-over credits are medium- or long-term loans on which the nominal interest rate is adjusted semi-annually. Such loans have increased in importance during the 1970s (Einzig, 1973).

To begin with the more simple case of multi-currency bonds, their existence is a result of indivisibilities in the market. If capital markets were perfect, any investor or borrower could protect himself against the divergence in inflation rates characteristic of the 1970s by obtaining an optimal mix of currencies. In the real world, however, relatively small investors or borrowers cannot diversify in this way without incurring high transactions costs. Instead, multi-currency bonds may serve as a substitute for holding many currencies. They make it possible for more lenders and borrowers to diversify their portfolios according to the dictates of portfolio theory.

Multi-currency bonds do not affect any of the assumptions underlying the analysis here. In contrast, roll-over credits introduce flexibility to the nominal interest rate. Einzig (1973) argues that high and uncertain inflation rates raise the demand for loans on which interest rates are adjustable. When uncertainty is high, borrowers who expect nominal interest rates to fall wish to borrow with a flexible interest rate. Borrowers who expect nominal rates to rise wish to borrow with a fixed interest rate. Einzig's uncertainty could therefore better be called heterogeneous expectations.

Nevertheless, it can be shown that even when all investors have identical

expectations, long-term investors and borrowers are likely to shift toward a succession of short-term loans instead of one long-term loan with a fixed nominal interest rate. For this shift to occur in response to rising inflation risk, the following conditions must occur:

a. Short-term nominal interest rates must adjust to inflationary expectations.

b. When the inflation rate for the near future becomes more or less predictable, the long-run inflation rate must also be regarded as more or less predictable. It could otherwise be argued that the long-run inflation rate is always very uncertain.

c. The variance of the nominal interest rates on short-term bonds must be dominated by the variance of the expected inflation rate.<sup>1</sup>

Under these conditions, it can be expected that roll-over credits will be issued in response to the higher inflation risk. The assumption of fixed nominal interest rates is therefore less likely to be correct the higher the uncertainty about inflation, and the analysis of inflation risk must be modified accordingly. Nevertheless, as long as the nominal interest rate does not adjust perfectly to the actual inflation rate, investors will face some inflation risk.

The analysis of exchange risk is not affected by the flexibility of nominal interest rates in response to changes in the inflation rate. Since exchange risk is asymmetrical, no linking can decrease it for all investors. Take, for example, the case of a country that links its nominal interest rate to the dollar exchange rate. Americans investing in that country would not face exchange risk but domestic residents would.

## 6.2 *Forward Markets for Foreign Exchange*

The analysis has thus far been carried out without reference to forward markets. The reason is that in a portfolio framework, within which investors can always optimize their portfolio of currencies, forward markets have no independent role to play. Investors diversify risks by obtaining net positions in currencies according to the rates of return and the risks of different currencies. As long as this is possible, there is no need to cover an investment in a foreign asset unless a foreign asset with forward cover has distinctly different risk characteristics from an asset denominated in the domestic currency. If there are no risks other than currency risks to consider, a foreign investment with forward cover is *identical* to a domestic investment: the two alternatives are perfect substitutes and interest-rate

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<sup>1</sup> For elaboration of these points, see Wihlborg (1976, Chap. 3).

parity must hold. Thus, in the analysis above, domestic-currency assets include investments in foreign-currency assets with forward cover. (For more elaboration, see Wihlborg, 1978b.)

Forward markets must exist then because of imperfections in the international capital markets. It is not difficult to find such imperfections. Traders taking positions in certain currencies in their export-import transactions may not be able to offset their foreign-currency positions with borrowing or lending in order to obtain an optimal portfolio. Forward markets may then be the cheapest way to improve their currency position. Credit rationing may be another reason why borrowers and investors are unable to obtain the desired mix of currencies. Again, forward markets provide a channel through which the desired currency mix can be obtained.

There are certainly many market participants to whom forward markets are crucial for obtaining the desired portfolios. The higher the risks and the lower the correlations between the rates of return in different currencies, the more important it is that market participants be able to diversify their portfolios in order to minimize exposure to risks. Forward markets, like multi-currency bonds, increase the effectiveness of international financial markets by providing a less costly way of shifting between currency positions to market participants who for one reason or another cannot obtain the desired currency mix simply by borrowing and lending.

## 7 SUMMARY AND IMPLICATIONS

There is no doubt that the risk characteristics of international financial investments have changed considerably during the past five years of increasingly flexible exchange rates. Exchange risk, the risk on short-term positions in foreign currencies defined as the variance of the change in the deviation from PPP, has increased considerably. Inflation risk has also increased for many currencies. This risk, defined as the variance of an inflation rate, is the risk associated with investments in specific currencies independent of the residency of the investor. Finally, correlations between the inflation rates of different countries have decreased.

It has been argued here that these changes are not a necessary consequence of flexible exchange rates. Instead, both high exchange risk and high inflation risk may have the same source—the unpredictability of inflation rates as a result of the unpredictability of central-bank behavior. As a result, arbitrageurs have difficulty predicting the future equilibrium exchange rate, so that their activities are less likely to be stabilizing. Under more favorable circumstances for stabilizing arbitrage activity, the fluctuations in the exchange rates and the deviations from PPP need not have been so wide.

To increase the predictability of future equilibrium exchange rates, monetary authorities should probably behave in a way completely different from the way they behaved under fixed-exchange-rate or adjustable-peg regimes. Under those regimes, it was important that the actions of central banks be unanticipated if traditional stabilization policies and adjustments of exchange rates were to achieve the desired results. If a devaluation could be clearly foreseen, nominal wages and other nominal variables could easily adjust and offset its effects. But, under flexible rates, the same secrecy of behavior will create uncertainty in the foreign-exchange markets and contribute to both exchange risk and inflation risk.

So far, there is no empirical evidence that trade flows have been deterred by high exchange risk, but such an effect should be expected. Although it is difficult to say how much influence should be attributed to exchange and inflation risks relative to other determinants of international trade, there are two reasons to expect some effect on trade flows. First, transactions costs rise in the foreign-exchange markets, spot as well as forward, if foreign-exchange dealers face more risk in their transactions. Aliber (1976) provides evidence that transactions costs have, in fact, risen. Second, smoothly functioning financial markets are important to ex-

porters and importers in financing trade. High inflation risk tends to thin out markets for certain currencies and high exchange risk tends to thin out foreign-exchange markets. Investments denominated in one currency are then not so easily transferred to investments in other currencies, and traders' exposure to risk increases.

A positive welfare effect of recent developments and of flexible exchange rates must also be noted. The decreased correlation between countries' inflation rates that has occurred and is likely to continue under a flexible-exchange-rate regime makes it possible for an investor to diversify away a good deal of inflation risk. With fixed exchange rates, all countries must necessarily have very similar inflation rates. If the common inflation rate is unpredictable, there is very little investors can do to hedge against the risk except to shorten lending and borrowing contracts. But this is costly. With flexible rates, investors can spread their lending and borrowing over many currencies, thereby decreasing the total inflation risk they face.

## APPENDIX

### A SIMPLE TWO-ASSET MODEL OF PORTFOLIO CHOICE

In this mean-variance model, there are two countries and two assets. Investors optimize expected utility over one period. They form expectations about inflation rates and exchange rates and evaluate the variances of these variables. Nominal interest rates are known with certainty.

Expected utility is a function of the expected real return ( $\mu$ ) and the variance ( $\sigma^2$ ) of the portfolio. In order to concentrate the analysis on the first two moments of probability distributions, it must be assumed that the rates of return, inflation rates, and changes in the exchange rate are normally distributed. With this assumption, we can use an exponential utility function. Denote the level of utility  $L$ :

$$L(r) = K - b \cdot \exp(-cr), \quad (\text{A-1})$$

where  $r$  is the real rate of return,  $K$  is a constant, and  $c$  is the measure of risk aversion. The key property of this utility function is *constant absolute risk aversion* (Borch, 1968).

Asset A is denominated in the domestic currency, and asset B is denominated in the foreign currency. The proportions of the two assets in an individual's portfolio are  $\alpha_A$  and  $\alpha_B$ , respectively ( $\alpha_A + \alpha_B = 1$ ). The expected real rates of return on assets A and B are  $r_A$  and  $r_B$ , respectively. The variances are  $\sigma_A^2$ ,  $\sigma_B^2$ , and the covariance is  $\sigma_{AB}^2$ .

$$\mu = \alpha_A r_A + \alpha_B r_B \quad (\text{A-2})$$

$$\sigma^2 = \alpha_A^2 \sigma_A^2 + \alpha_B^2 \sigma_B^2 + 2\alpha_A \cdot \alpha_B \cdot \sigma_{AB}^2, \quad (\text{A-3})$$

where

$$\sigma_{AB}^2 = \sigma_A \cdot \sigma_B \cdot \rho_{AB} \quad (\text{A-4})$$

and  $\rho_{AB}$  is the correlation coefficient. It is assumed that transactions costs are zero and that there are no limits on going short in any assets. Expression (A-1) can be expressed in terms of  $\mu$  and  $\sigma^2$ . Denote the expected utility  $E(L)$ :

$$E(L) = K - b \cdot \exp[-c(\mu - c/2 \cdot \sigma^2)]. \quad (\text{A-5})$$

Inserting (A-2), (A-3), and (A-4) into (A-5) gives the optimization problem. Recall also that  $\alpha_B = 1 - \alpha_A$ .



$$\begin{aligned} \text{Max } E(L) = & K - b \cdot \exp(-c\{[\alpha_A \cdot r_A + (1 - \alpha_A)r_B] \\ & - c/2[\alpha_A^2 \cdot \sigma_A^2 + (1 - 2\alpha_A + \alpha_A^2) \cdot \sigma_B^2 \\ & + 2(\alpha_A - \alpha_A^2) \cdot \sigma_A \cdot \sigma_B \cdot \rho_{AB}]\}). \end{aligned} \quad (\text{A-6})$$

Maximize with respect to  $\alpha_A$ , or the proportions of the two assets in the portfolio. At maximum,  $[\delta E(L)]/\delta \alpha_A = 0$ . Thus,

$$\begin{aligned} \frac{\delta E(L)}{\delta \alpha_A} = & + bc ([r_A - r_B] - c/2[2\alpha_A \cdot \sigma_A^2 - 2\sigma_B^2 \\ & + 2\alpha_A \cdot \sigma_B^2 + 2\sigma_A \cdot \sigma_B \cdot \rho_{AB} - 4\alpha_A \cdot \sigma_A \cdot \sigma_B \cdot \rho_{AB}]) \\ & \cdot \exp[-c(\dots)] = 0. \end{aligned} \quad (\text{A-7})$$

$[\delta E(L)]/\delta \alpha_A$  is 0 when the expression before  $\exp = 0$ , i.e., when

$$\begin{aligned} bc ([r_A - r_B] - c/2[2\alpha_A(\sigma_A^2 + \sigma_B^2 - 2\sigma_A \cdot \sigma_B \cdot \rho_{AB}) \\ + 2(\sigma_B^2 - \sigma_A \cdot \sigma_B \cdot \rho_{AB})]) = 0. \end{aligned} \quad (\text{A-8})$$

The second-order condition for maximum is that  $[\delta^2 E(L)]/\delta \alpha_A^2 < 0$ , i.e.,

$$\frac{\delta^2 E(L)}{\delta \alpha_A^2} < 0 \quad \text{when} \quad 2(\sigma_A^2 + \sigma_B^2 - 2\sigma_A \cdot \sigma_B \cdot \rho_{AB}) > 0. \quad (\text{A-9})$$

Clearly, we have a maximum by (A-8). From (A-8) we get the optimal proportions:

$$\alpha_A = \frac{(r_A - r_B) + c(\sigma_B^2 - \sigma_A \cdot \sigma_B \cdot \rho_{AB})}{c(\sigma_A^2 + \sigma_B^2 - 2\sigma_A \cdot \sigma_B \cdot \rho_{AB})} \quad (\text{A-10})$$

and, of course,  $\alpha_B$ , the proportion of the other asset in the portfolio, is  $(1 - \alpha_A)$ .

The risks will now be specified as inflation risk and exchange risk, but the analysis is of course applicable to any kind of risk. The notation continues to be that  $\alpha_A$  is the proportion of assets denominated in the domestic currency and  $\alpha_B$  the proportion denominated in the foreign currency. The expected real rate of return on asset A and the variance of the domestic rate of return are

$$r_A = r_A^N - \hat{P}_A \quad \text{and} \quad \sigma_A^2 = \sigma_{\hat{P}_A}^2, \quad (\text{A-11})$$

where  $r_A^N$  is the nominal interest rate in country A,  $\hat{P}_A$  is the expected rate of inflation in A, and  $\sigma_{\hat{P}_A}^2$  is the variance of the domestic inflation rate at the target date.

The real rate of return on asset B is

$$r_B = r_B^N + \hat{X} - \hat{P}_A = r_B^N - \hat{P}_B + \hat{U}, \quad (\text{A-12})$$

and the variance is  $\sigma_B^2 = \sigma_{\hat{P}_B}^2 + \sigma_{\hat{U}}^2$ , where  $\hat{X}$  is the expected rate of change in the exchange rate and  $\sigma_{\hat{U}}^2$  is exchange risk. It is assumed that the rate of inflation and the rate of change of deviations from PPP( $\hat{U}$ ) are independent.

The correlation between real rates of return will consist only of the correlation between inflation rates:

$$\rho_{AB} = \rho(\hat{P}_A, \hat{P}_B). \quad (\text{A-13})$$

Note that the expression within parentheses in the denominator in (A-10) is equal to the variance of the expected rate of change in the exchange rate ( $\sigma_{\hat{X}}^2$ ).

### *The Condition for a Positive Net Wealth Position in a Currency*

Since the denominator in (A-10) is positive,

$$\alpha_A \geq 0 \quad \text{if} \quad r_A - r_B \geq -c(\sigma_B^2 - \sigma_A \cdot \sigma_B \cdot \rho_{AB}). \quad (\text{A-14})$$

$r_B$  must not be so much higher than  $r_A$  that it compensates for the variance of the foreign rate of return minus the covariance between the domestic and the foreign rates of return.  $\alpha_A > 0$  is identical to  $\alpha_B < 1$ .

Next we find the conditions for  $\alpha_A \geq 1$ :

$$\alpha_A \geq 1 \quad \text{if} \quad r_A - r_B \geq c(\sigma_A^2 - \sigma_A \cdot \sigma_B \cdot \rho_{AB}). \quad (\text{A-15})$$

i.e., the interest-rate differential must compensate for the valuation of the variance in country A minus the covariance.  $\alpha_A \geq 1$  is identical to  $\alpha_B \leq 0$ .

### *Changes in Expected Returns and Portfolio Choice*

The change in optimal proportions of the two assets in the portfolio occasioned by a change in the difference between expected real returns is derived from (A-10).

$$\frac{\delta \alpha_A}{\delta(r_A - r_B)} = \frac{1}{c\sigma_{\hat{X}}^2} > 0. \quad (\text{A-16})$$

The desired proportion of an asset increases with its expected rate of return. This follows, of course, from an assumption about positive marginal utility of income.

### Changes in Risks and Portfolio Choice

To determine the change in desired proportions in response to changes in risk, first differentiate with respect to domestic inflation risk (the standard deviation of the domestic inflation rate):

$$\begin{aligned} \frac{\delta\alpha_A}{\delta\sigma_A} = & \{c \cdot \sigma_X^2(-\sigma_B \cdot \rho_{AB}) - [(r_A - r_B) \\ & + c(\sigma_B^2 - \sigma_A \cdot \sigma_B \cdot \rho_{AB})] \\ & \cdot [2c\sigma_A - 2c\sigma_B \cdot \rho_{AB}]\} / [c^2 \cdot (\sigma_X^2)^2]. \end{aligned} \quad (\text{A-17})$$

(A-17) can be rewritten by utilizing (A-10), the expression for  $\alpha_A$ :

$$\frac{\delta\alpha_A}{\delta\sigma_A} = \frac{-\sigma_B \cdot \rho_{AB}}{\sigma_X^2} - 2\alpha_A \cdot \frac{(\sigma_A - \sigma_B \cdot \rho_{AB})}{\sigma_X^2}, \quad (\text{A-18})$$

where  $\frac{\delta\alpha_A}{\delta\sigma_A} < 0$  if  $\alpha_A > \frac{-\sigma_B \cdot \rho_{AB}}{2(\sigma_A - \sigma_B \cdot \rho_{AB})}$ .

If  $\rho_{AB} = 0$ , the condition is  $\alpha_A > 0$ . That is, an increase in inflation risk in a currency leads to a demand for a lower proportion of assets denominated in that currency if initial holdings are positive and to a demand for a higher proportion if initial holdings are negative.

### Correlations between Returns and Portfolio Choice

To determine the change in desired proportions in response to changes in the correlation and the covariance between returns, first differentiate with respect to the covariance:

$$\begin{aligned} \frac{\delta\alpha_A}{\delta \text{COV}_{AB}} = & \frac{-c^2\sigma_X^2 - [(r_A - r_B) + c(\sigma_B^2 - \sigma_A \cdot \sigma_B \cdot \rho_{AB})] \cdot 2c}{(c \cdot \sigma_X^2)^2} \\ = & -\frac{1 - 2\alpha_A}{\sigma_X^2}. \end{aligned} \quad (\text{A-19})$$

This implies that  $\frac{\delta\alpha_A}{\delta \text{COV}_{AB}} > 0$  if  $(2\alpha_A - 1) > 0$ , i.e., if  $\alpha_A > \frac{1}{2}$ .

$$\frac{\delta\alpha_A}{\delta\rho_{AB}} = \frac{\sigma_A\sigma_B}{\sigma_X^2}(2\alpha_A - 1) \quad \text{or} \quad \frac{\delta\alpha_A}{\delta\rho_{AB}} > 0 \quad \text{if} \quad \alpha_A > \frac{1}{2}, \quad (\text{A-20})$$

which is exactly the same condition as in (A-19).

### *Changes in Risks and Elasticities*

Here we start from (A-16), the expression for

$$\frac{\delta\alpha_A}{\delta(r_A - r_B)}.$$

To see how elasticities change with changes in risk, given  $\alpha_A$ ,  $\alpha_B$ ,  $r_A$ , and  $r_B$ , we study

$$\left[ \delta \frac{\delta\alpha_A}{\delta(r_A - r_B)} \right] / \delta\sigma,$$

where  $\sigma$  is any kind of risk. First, note that the elasticity decreases with an increase in the variance of the exchange rate from an unspecified source:

$$\left[ \delta \frac{\delta\alpha_A}{\delta(r_A - r_B)} \right] / \delta\sigma_x^2 = - \frac{1}{(c\sigma_x^2)^2} < 0. \quad (\text{A-21})$$

Second, one of the inflation variances increases:

$$\left[ \delta \frac{\delta\alpha_A}{\delta(r_A - r_B)} \right] / \delta\sigma_A = - \frac{2\sigma_A - \sigma_B \cdot \rho_{AB}}{(c\sigma_x^2)^2} < 0 \quad \text{if} \quad 2\sigma_A > \sigma_B \cdot \rho_{AB}.$$

In words, an increase in one risk decreases the elasticity if the other risk is not much larger when the correlation is very high.<sup>1</sup>

Finally, an increase in the correlation leads to an increase in the elasticity:

$$\left[ \delta \frac{\delta\alpha_A}{\delta(r_A - r_B)} \right] / \delta\rho_{AB} = - \frac{1 \cdot (-2\sigma_A \cdot \sigma_B)}{(c\sigma_x^2)^2} > 0. \quad (\text{A-22})$$

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<sup>1</sup> The condition is identical to a condition for a higher exchange-rate variance as a result of an increase in the variance of one inflation rate.

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