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What Macroeconomic Risks Are (Not) Shared by International Investors?

Adopting an asset-market view of international risk sharing, we identify various sources of macroeconomic risk faced by international investors using a structural Vector Autoregression model. We find that most of the risks of exogenous financial market shocks are shared by international investors through the existing asset markets. However, other macroeconomic risks such as those associated with exogenous shocks to consumption growth, inflation and monetary policies are not fully shared across countries. This finding helps us understand the apparently contradicting perceptions of international risk sharing generated by the analysis of asset-market returns versus that of aggregate consumption growth across countries.

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If markets were complete and if there were no transport costs, the standard economic theory predicts that we would have perfect risk sharing across national borders. In such a case, the growth rates of marginal utility would be equal across countries as international investors are able to pool all of the idiosyncratic risks they face. In reality, however, a significant part of consumption goods is non-tradables, and transport costs vary by goods and country pair. Moreover, international financial markets are far from being complete. There is no shortage

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of examples of market frictions such as liquidity and short-sale constraints as well as government restrictions on holdings of foreign assets. These imperfections are likely to introduce a wedge between the marginal utilities of consumption in different countries.

Most empirical studies based on aggregate consumption, including Canova and Ravn (1996), Crucini (1999), Lewis (1996), and Pakko (1998) among others, have concluded that international risk sharing is poor. In fact, correlations between consumption growth rates across countries are even weaker than correlations between output growth rates (Backus, Kehoe, and Kydland 1992). This observation supports the view that individuals have not done a good job of hedging risks across countries (Lewis 1999) and, therefore, gains from international risk sharing could be very large (Van Wincoop 1999).

The marginal utility of consumption is, however, not observable. To assess the degree of international risk sharing based on aggregate consumption, one needs to make specific assumptions about an individual's utility function. For example, under the conventional assumption of power utility function, equality of two countries' marginal utility growth rates implies equal consumption growth rates for the two countries. It is well known that such a utility function fails to reconcile the observed high equity premium with consumption data even in a single-country setting.[1] In addition, limited participation in asset markets is yet another challenge to the empirical studies of international risk sharing relationship based upon aggregate consumption.[2]

A recent study by Brandt, Cochrane, and Santa-Clara (2001) obtains a very different result about the degree of international risk sharing. Recognizing that the real exchange rate moves by the domestic–foreign marginal utility growth differential,[3] they derive the information about the marginal utility growth directly from asset returns. They find that investors face a considerable amount of risks on one hand, as measured by the large volatility of the marginal utility growth. On the other hand, they find that the correlation of the marginal utility growth rates between the two countries is very high, implying that these risks are shared surprisingly well by international investors using the existing asset markets.

Using the above asset-pricing approach of international risk sharing, this paper addresses the following empirical questions: What macroeconomic risks are shared (or not shared) by investors who participate in the international asset markets? How well do international investors insure against different kinds of idiosyncratic shocks to the economy using the existing asset markets? To this end, we incorporate the asset-market view of international risk sharing into a nonlinear structural Vector

1. See, for example, Kocherlakota (1996) for an excellent survey of the literature on the equity premium puzzle.

2. For example, Davis, Nalewaik, and Willen (2000) find that limited participation goes a long way toward addressing the international risk sharing puzzle.

3. Backus and Smith (1993) found, however, that, under the assumption of an isoelastic utility function, the correlation between the domestic–foreign marginal utility growth differential and the real exchange rate is not strong. This may simply reflect the inadequacy of the period utility function used in their model. Moreover, if markets are not complete, there also exists a wedge between the real exchange rate and the marginal utility growth differential.

Autoregression (VAR) model that identifies various sources of macroeconomic risks, including exogenous shocks to domestic and foreign consumption growth, inflation, and monetary policies as well as exogenous shocks to asset markets. We then examine the dynamic effect of these shocks on the domestic–foreign marginal utility growth differential, which is approximated by the real depreciation of the domestic currency. If one macroeconomic risk is fully shared by international investors, then domestic and foreign marginal utility growth rates would move together in response to the shock. Hence, their *difference* would not be affected by this shock, and the shock should account for little of the volatility of the change in the real exchange rate. Our main finding is that international investors are actually doing a very good job of hedging against the risk of exogenous shocks to asset markets, although they are not able to fully share other macroeconomic risks, most likely due to market incompleteness and transport costs.

There has been an increasingly large body of literature on international macroeconomics, stressing the importance of fluctuations of the real exchange rate in accounting for the cross-country co-movement of consumption and output.[4] While the real exchange rate plays a crucial role in our approach, the goal of the current paper is to document some empirical facts about international risk sharing from a new perspective, rather than to examine the deep structural relationship between the real exchange rate and consumption. The rest of this paper is organized as follows: Section 1 lays out the empirical model used in the paper, Section 2 discusses the main results, and Section 3 provides a summary. All appendices to this paper are available at this journal's web site as well as in the working paper version.

1. THE MODEL

In this section, we first outline the theoretical framework that motivates our empirical specification. We then incorporate this asset-market view of international risk sharing into a structural VAR analysis with various sources of macroeconomic risk.

1.1 The Framework

The key economic relationship underlying our empirical analysis is that, under the assumption of absence of arbitrage in international financial markets, variations in the real exchange rate can be directly linked to the difference between the growth rates of marginal utility of domestic and foreign investors, i.e.

$$\log S_{t+1} - \log S_t = -(\log M_{t+1} - \log M^*_{t+1}) \,, \tag{1}$$

where S_t is the real exchange rate (in units of domestic goods/foreign goods) between the two countries, and $\log M_{t+1}$ and $\log M^*_{t+1}$ are the growth rates of the domestic

4. See, for example, Chari, Kehoe, and McGrattan (1998), Obstfeld and Rogoff (1999), Betts and Devereux (2000), and Ravn (2001) among others.

and foreign marginal utility, respectively (see Appendix A for details of derivation of this and other relations in this section).[5]

Under perfect risk sharing, M_{t+1} and M^*_{t+1} would be equal and hence, the real exchange rate would remain constant. If risk sharing is poor, $\Delta\log S_{t+1}$ will fluctuate as $\log M_{t+1}$ and $\log M^*_{t+1}$ move differently in response to various economic shocks. The main advantage of this asset-market view of international risk sharing is that one does not have to make assumptions about the functional form of (or the inputs into) the utility function of international investors.[6]

To get a useful empirical specification, we assume that M_{t+1} and M^*_{t+1} both follow the log-normal distribution. More specifically, it is assumed that

$$\log M_{t+1} = \mu_t - \boldsymbol{\lambda}_t'\boldsymbol{\varepsilon}_{t+1} \text{ and } \log M^*_{t+1} = \mu^*_t - \boldsymbol{\lambda}^{*\prime}_t\boldsymbol{\varepsilon}_{t+1}\,, \tag{2}$$

where $\mu_t = E_t(\log M_{t+1})$, $\mu^*_t = E_t(\log M^*_{t+1})$, and the term $\boldsymbol{\varepsilon}_{t+1}$ represents a vector of fundamental economic shocks (to be described below) distributed as $\boldsymbol{\varepsilon}_t \sim N(\mathbf{0},\mathbf{I})$. Parameters $\boldsymbol{\lambda}_t$ and $\boldsymbol{\lambda}^*_t$ are referred to in the literature as the market prices of risk. It follows from Equation (1) that

$$\Delta\log S_{t=1} - (i_t - i^*_t) = \frac{1}{2}(\boldsymbol{\lambda}_t'\boldsymbol{\lambda}_t - \boldsymbol{\lambda}^{*\prime}_t\boldsymbol{\lambda}^*_t) + (\boldsymbol{\lambda}_t - \boldsymbol{\lambda}^*_t)'\boldsymbol{\varepsilon}_{t+1}\,, \tag{3}$$

where i_t and i^*_t are the one-period risk-free real interest rates in the home and foreign country, respectively.

It is easy to see from Equation (3) that the conventional uncovered interest rate parity (UIP) does not hold in general, or

$$\phi_t \equiv E_t\Delta\log S_{t+1} - (i_t - i^*_t) \neq 0\,. \tag{4}$$

Note the UIP deviation ϕ_t can be decomposed as $\phi_t = u_t + v_t$, where $u_t = (\boldsymbol{\lambda}_t - \boldsymbol{\lambda}^*_t)'\boldsymbol{\lambda}_t$ and $v_t = -(1/2)(\boldsymbol{\lambda}_t - \boldsymbol{\lambda}^*_t)'(\boldsymbol{\lambda}_t - \boldsymbol{\lambda}^*_t)$. Using Equations (2) and (3), u_t can be expressed as

$$u_t = \mathrm{Cov}_t[\Delta\log S_{t+1} - (i_t - i^*_t), -\log M_{t+1}]\,. \tag{5}$$

In other words, u_t is the conditional covariance between the excess return on the foreign exchange and the log of the stochastic discount factor, or in short, the risk premium from investing in the foreign exchange. By Equation (2), we can write u_t as

$$u_t = \sum_{i=1}^{N}\lambda_{i,t}\,\mathrm{Cov}[\Delta\log S_{t+1} - (i_t - i^*_t), \varepsilon_{i,t+1}]\,, \tag{6}$$

which explains why $\boldsymbol{\lambda}_t$ is called the market prices of risk. The i-th component λ_{it} of

5. See Brandt, Cochrane, and Santa-Clara (2001). Other studies that also exploit this relationship include Backus, Foresi and Telmer (2001), Brandt and Santa-Clara (2002), and Hollifield and Yaron (2000).

6. See Section 2.4 for discussions of the major caveats of this approach.

$\boldsymbol{\lambda}_t$ prices the covariance between the foreign exchange return and the i-th fundamental economic shock.[7]

Let r_t and r_t^* be the domestic and foreign real stock returns. Under the no-arbitrage condition and log-normal assumption, we similarly obtain

$$r_{t+1} - i_t = -\frac{1}{2}\boldsymbol{\sigma}'\boldsymbol{\sigma} + \boldsymbol{\sigma}'\boldsymbol{\lambda}_t + \boldsymbol{\sigma}'\boldsymbol{\varepsilon}_{t+1}\,, \tag{7}$$

$$r_{t+1}^* - i_t^* = -\frac{1}{2}\boldsymbol{\sigma}^{*'}\boldsymbol{\sigma}^* + \boldsymbol{\sigma}^{*'}\boldsymbol{\lambda}_t^* + \boldsymbol{\sigma}^{*'}\boldsymbol{\varepsilon}_{t+1}\,, \tag{8}$$

where $\boldsymbol{\sigma}$ and $\boldsymbol{\sigma}*$ are the volatilities of the stock returns.

Equation (3) together with Equations (7) and (8) can be used to find a link between the excess returns and macroeconomic shocks. In what follows, we will also model $\boldsymbol{\lambda}_t$ and $\boldsymbol{\lambda}_t^*$ as functions of observable macroeconomic variables,[8] which are in turn driven by the fundamental shocks.

1.2 A Nonlinear VAR Model

We postulate two types of structural shocks in our analysis. One includes exogenous innovations to consumption growth, inflation, and monetary policies in the home and foreign countries. The other is the exogenous financial market shock orthogonal to those macroeconomic shocks. More specifically, we assume that $\boldsymbol{\varepsilon}_t$ has nine components[9]: $\boldsymbol{\varepsilon}_t = (\boldsymbol{\varepsilon}'_{Y,t}, \boldsymbol{\varepsilon}'_{\Pi,t}, \boldsymbol{\varepsilon}'_{M,t}, \boldsymbol{\varepsilon}'_{S,t})'$, where $\boldsymbol{\varepsilon}_{Y,t} = (\varepsilon_{y,t}, \varepsilon^*_{y,t})'$ and $\boldsymbol{\varepsilon}_{\Pi,t} = (\varepsilon_{\pi,t}, \varepsilon^*_{\pi,t})'$ can be thought of as the home and foreign countries' aggregate supply and demand shocks, respectively, while $\boldsymbol{\varepsilon}_{M,t} = (\varepsilon_{m,t}, \varepsilon^*_{m,t})'$ includes exogenous shocks to monetary policies in the two countries and $\boldsymbol{\varepsilon}_{S,t} = (\varepsilon_{s,t}, \varepsilon_{r,t}, \varepsilon^*_{r,t})'$ represents exogenous shocks to international financial markets, including the exogenous innovations to the foreign exchange rate as well as the domestic and foreign stock market returns.

Let $\mathbf{z}_t$ be a 9×1 vector of macroeconomic variables that summarizes the current state of the economy. We include in $\mathbf{z}_t$ the home and foreign consumption growth rates (y_t and y_t^*), inflation rates (π_t and π_t^*) as well as real short-term interest rates (i_t and i_t^*) in the two countries. The last three components of $\mathbf{z}_t$ are the change in the real exchange rate ($\Delta\log S_t$) and the domestic and foreign real stock returns (r_t and r_t^*).

7. For example, if $\varepsilon_{i,t+1}$ is an exogenous shock to monetary policy in the home country, then the risk associated with the policy when investing in the foreign exchange is characterized by the conditional covariance between the foreign exchange return and the policy shock, and $\lambda_{i,t}$ is the expected excess rate of return per unit of such covariance. Note that similar results hold for the foreign country as well. The foreign exchange risk premium for foreign investors can be expressed as $u_t^* = \sum_{i=1}^{N} \lambda^*_{i,t}\mathrm{Cov}_t[-\Delta\log S_{t+1} - (i_i^* - i_t), \varepsilon_{i,t+1}]$, and the similar interpretation applies to $\lambda^*_{i,t}$.

8. In the finance literature, there have been several trials to use observable economic variables as priced risk factors in asset-pricing models, including classic studies by Chen, Roll, and Ross (1986), Chan, Chen and Hsieh (1985), and Ferson and Harvey (1991). More recently, Ang and Piazzesi (2001) incorporated macroeconomic variables in a VAR analysis of the term structure of interest rates.

9. We can easily generalize the model to include more economic shocks.

We assume that the market prices of risk are linear functions of $\mathbf{z}_t$[10]

$$\boldsymbol{\lambda}_t = \boldsymbol{\Gamma}\mathbf{z}_t \text{ and } \boldsymbol{\lambda}_t^* = \boldsymbol{\Gamma}^*\mathbf{z}_t\,, \tag{9}$$

where $\boldsymbol{\Gamma}$ and $\boldsymbol{\Gamma}^*$ are 9×9 matrices. The dynamics of the first six components of $\mathbf{z}_t$ (denoted by $\mathbf{z}_t^+$) is assumed to be described by the following reduced-form equation

$$\mathbf{z}_t^+ = \boldsymbol{\mu} + \mathbf{B}_1^+\mathbf{z}_{t-1} + \cdots + \mathbf{B}_p^+\mathbf{z}_{t-p} + \mathbf{u}_t^+\,, \tag{10}$$

where $\mathbf{z}_t = (\mathbf{z}_t^{+\prime}, \Delta\log S_t, r_t, r_t^*)'$, $\mathbf{B}_1^+,\ldots,\mathbf{B}_p^+$ are 6×9 matrices and $\boldsymbol{\mu}$ is a 6×1 vector of constants. The $\mathbf{u}_t^+$ stands for a vector of one-step-ahead forecast errors and it is assumed that $\mathbf{u}_t^+ \sim N(0,\boldsymbol{\Sigma})$, where $\boldsymbol{\Sigma}$ is a symmetric positive definite matrix. The error term $\mathbf{u}_t^+$ is related to the structural shocks according to $\mathbf{u}_t^+ = \mathbf{C}\boldsymbol{\varepsilon}_t$, where $\mathbf{C}$ is a 6×9 matrix. Using Equations (3), (7), and (8) together with Equation (9), the last three components of $\mathbf{z}_t$ may be written as

$$\Delta\log S_t = (i_{t-1} - i_{t-1}^*) + (1/2)\mathbf{z}_{t-1}(\boldsymbol{\Gamma}'\boldsymbol{\Gamma} - \boldsymbol{\Gamma}^{*\prime}\boldsymbol{\Gamma}^*)\mathbf{z}_{t-1} + \mathbf{z}_{t-1}'(\boldsymbol{\Gamma} - \boldsymbol{\Gamma}^*)'\boldsymbol{\varepsilon}_t\,, \tag{11}$$

$$r_t = -\frac{1}{2}\boldsymbol{\sigma}'\boldsymbol{\sigma} + \boldsymbol{\sigma}'\boldsymbol{\Gamma}\mathbf{z}_{t-1} + i_{t-1} + \boldsymbol{\sigma}'\boldsymbol{\varepsilon}_{t+1}\,, \tag{12}$$

$$r_t^* = -\frac{1}{2}\boldsymbol{\sigma}^{*\prime}\boldsymbol{\sigma}^* + \boldsymbol{\sigma}^{*\prime}\boldsymbol{\Gamma}^*\mathbf{z}_{t-1} + i_{t-1}^* + \boldsymbol{\sigma}^{*\prime}\boldsymbol{\varepsilon}_{t+1}\,. \tag{13}$$

Equations (10)–(13) therefore, constitute a constrained nonlinear VAR, on which our empirical analysis will be based.

1.3 Identification

In conventional linear VAR models, the identification problem reduces to the restrictions on matrix $\mathbf{C}$. In the nonlinear VAR model outlined above, it is necessary to identify the pricing matrices $\boldsymbol{\Gamma}$ and $\boldsymbol{\Gamma}^*$ as well. We discuss these two identification conditions in turn.

*Identification of **C***. We impose the following restrictions to identify the macroeconomic shocks. First, since it is widely believed that monetary policy actions only affect the real economy as well as inflation with a delay, we assume that consumption growth and inflation do not respond contemporaneously to shocks on monetary policies in both countries. We also assume that exogenous shocks to the exchange rate and stock returns have no immediate impact on consumption growth and inflation. This kind of recursive identification assumption is commonly used in the monetary VAR literature (e.g., Christiano, Eichenbaum, and Evan 1999).

Second, we assume that, when setting its policy instrument, the monetary authority in one country does not respond immediately to the other country's aggregate supply and demand shocks, or its monetary policy shocks. The main reason is that

10. Similar parameterizations of the market price of risk have been widely used in the literature where $\mathbf{z}_t$ is treated as a latent state variable, including Constantinides (1992), Ahn, Dittmar, and Gallant (2000), and Dai and Singleton (2002) among others.

the exact information about a foreign country's output, price, and monetary policy stance may not be available immediately to the domestic central bank. Another reason is that the countries included in the current study are all large economies. Foreign shocks are hence less likely to produce a severe impact on the domestic economy that requires systematic monetary policy responses.

Finally, we allow monetary authorities to respond contemporaneously to the exogenous shocks to the exchange rate, but not to the innovations in the stock returns in our model. This is mainly because while stability in foreign exchange markets has been one of the major policy goals of all central banks, very rarely do monetary policies respond to the development in stock markets.

These identifying assumptions imply that the matrix **C** takes the following form:

$$\mathbf{C} = \begin{bmatrix} & \mathbf{C}_{11} & & & & & \mathbf{0} & & \\ \times & 0 & \times & 0 & \times & 0 & \times & 0 & 0 \\ 0 & \times & 0 & \times & 0 & \times & \times & 0 & 0 \end{bmatrix}, \qquad (14)$$

where $\mathbf{C}_{11}$ is a 4×4 matrix, $\mathbf{0}$ is a 4×5 matrix of zeroes, "0" indicates the zero restriction and "×" indicates a free parameter. In the following estimation we will further restrict $\mathbf{C}_{11}$ to be lower triangular, which is inconsequential for shocks aside from the first four.

Identification of $\mathbf{\Gamma}$ *and* $\mathbf{\Gamma}^*$. To identify $\mathbf{\Gamma}$ and $\mathbf{\Gamma}^*$, we make the following three assumptions (see Appendix B for more details). First, we assume that the domestic (U.S.) stock returns do not respond contemporaneously to an exogenous shock on the foreign stock returns, but not vice versa. Second, consistent with the usual representative-agent approach in macroeconomics, we assume that home investors and foreign investors price the risk factors in a symmetrical fashion as detailed in Appendix B. Third, we assume that the contribution of y_t^* to the market price of home consumption risk is equal in size to the contribution of y_t to the market price of foreign consumption risk. This assumption of symmetry is obviously a simplification.

The above set of identification assumptions corresponds to our baseline model.[11] We check the robustness of the results associated with these restrictions by estimating the model under alternative identification schemes in Section 2.5.

2. EMPIRICAL RESULTS

2.1 The Data and Estimation Results

The data used in this study are based on quarterly observations of aggregate consumption, consumer price indices (CPI), short-term interest rates, stock market returns, foreign exchange rates, and total population for Germany, Britain, Japan, and the U.S. over the period between 1973 and 1996. The data on international

11. Note that this set of restrictions is the minimum required for identification.

stock market returns are from Morgan Stanley Capital International Indices.[12] The data on other macroeconomic variables are from International Financial Statistics of the IMF. All variables except total population are in nominal terms. We obtain the real per capita consumption growth rate by subtracting the CPI inflation rate and population growth rate from the aggregate consumption growth rate. Similarly, the real interest rates, real stock returns, and the change in the real exchange rates are obtained by adjusting for the CPI inflation rates.[13]

Using the maximum likelihood method, we estimate the nine-variable VAR described in Section 1.2 separately for three pairs of countries: U.S./Germany, U.S./UK, and U.S./Japan. Given the large dimension of the model and limited data, we only allow for one lag in our VAR model in the current paper.[14]

Since our primary interest is in the properties of the real exchange rate movement under the exogenous macroeconomic shocks, in the following discussion we focus on the exchange rate equation given in Equation (11). Appendix B shows that the equation can be written as

$$\Delta \log S_t = \mathbf{z}'_{t-1}\mathbf{A}'_1\mathbf{B}_S\mathbf{A}_2\mathbf{z}_{t-1} + \mathbf{b}'\mathbf{z}_{t-1} + (\mathbf{C}_S\mathbf{z}_{t-1})'\boldsymbol{\varepsilon}_t\,, \tag{14}$$

where $\mathbf{B}_S$ and $\mathbf{C}_S$ are, respectively, 5×4 and 9×9 matrices whose elements are to be estimated, $\mathbf{b} = (0,0,0,0,1,-1,0,0,0)'$, and $\mathbf{A}_1$ and $\mathbf{A}_2$ are some constant matrices defined in Appendix B. Under the symmetry assumption, the matrix $\mathbf{C}_S$ has a simple structure with only seven unknown coefficients.

Two points are worth mentioning. First, it appears that stochastic volatility is an important characteristic of the exchange rate movements. The conditional variance of $\Delta \log S_t$ given $\mathbf{z}_{t-1}$ is determined by $\mathbf{z}'_{t-1}\mathbf{C}'_S\mathbf{C}_S\mathbf{z}_{t-1}$. The estimates of the parameters in $\mathbf{C}_S$ are reported in Table 1 and most elements are highly significant. Many previous VAR studies on the exchange rate usually assume homoskedasticity. Our result suggests that it is important to take into account the stochastic volatility in order to understand the dynamic behavior of the exchange rate. It is interesting to note that the most significant estimates of the elements in matrix $\mathbf{C}_S$ are C_{55}, C_{37}, and C_{57}, where C_{55} is the coefficient on the interest rates i_{t-1} and i^*_{t-1}, and both C_{37} and C_{57} are coefficients on the exchange rate $\Delta \log S_{t-1}$ (see Appendix B for the definition of matrix $\mathbf{C}_S$ and Section 1.2 for the definition of $\mathbf{z}_t$). This suggests that the lagged interest rates and the lagged exchange rate are the most important economic variables affecting the stochastic volatility of the exchange rate.

12. The data are generously provided to us by John Campbell of Harvard University. It is the same data set used in “Asset Price, Consumption and the Business Cycle” by John Campbell (1999) in the Handbook of Macroeconomics. More detailed information about the data can be found in Campbell (1999).

13. Note that we use the ex-post real interest rates, instead of the ex-ante real interest rates, in our empirical exercise. The impact of this choice on the estimation results is minimal because the dependent variables in the regression are the excess rates of returns; see Equations (3), (7), and (8).

14. Even with one lag, our model explains about 30% of the variation of the exchange rate change $\Delta \log S_t$ in all three cases. For the U.S./Germany exchange rate, the R^2 is 27.7%, and for the U.S./Japan and U.S./UK exchange rates the R^2 are 29.2% and 26.3%, respectively. The one-lag VAR system seems to offer a good approximation of the system dynamics.

Second, consistent with the findings in the large literature on the forward premium puzzle, we find that there is a substantial deviation from the uncovered interest rate parity and that the time-varying risk premiums are an important component of the exchange rate movements. In particular, given the exchange rate Equation (14), the ex-ante UIP deviation can be obtained as

$$\phi_t \equiv E_t[\Delta\log S_{t+1} - (i_t - i_t^*)] = \mathbf{z}_t'\mathbf{A}_1'\mathbf{B}_S\mathbf{A}_2\mathbf{z}_t \, ,$$

and the foreign exchange risk premiums as defined in Equation (5) is given by

$$u_t \equiv E_t[\Delta\log S_{t+1} - (i_t - i_t^*)] + \frac{1}{2}\mathrm{Var}_t(\Delta\log S_{t+1})$$

$$= z_t'\mathbf{A}_1'\mathbf{B}_S\mathbf{A}_2\mathbf{z}_t + \frac{1}{2}\mathrm{z}_t'\mathbf{C}_S'\mathbf{C}_S\mathbf{z}_t \, .$$

As in $\mathbf{C}_S$, many of the estimated elements in $\mathbf{B}_S$ are significant.[15] These estimates reject uncovered interest rate parity and constant foreign exchange risk premiums for all the countries we considered.

2.2 The Estimated Monetary Policy Behavior

In addition to the exchange rate equation, it is also interesting to note that the estimated monetary policy reaction function is largely consistent with the conventional view about how policy makers react to changes in particular economic variables. More specifically, the identification restrictions imposed on matrix **C** in Section 1.3 imply that the U.S. and foreign monetary policies react contemporaneously to various economic shocks according to the following equations (abstracting from all lagged variables)

TABLE 1

Estimates of the Matrix $\mathbf{C}_S$

	U.S./Germany Ex-Rate	U.S./UK Ex-Rate	U.S./Japan Ex-Rate
C_{11}	0.1786 (0.3813)	0.2844 (0.3400)	−2.4416 (0.7682)
C_{33}	0.3442 (0.4275)	0.6377 (0.3011)	−1.1371 (0.5359)
C_{55}	−3.2899 (0.6164)	−2.4110 (0.2759)	5.1335 (1.0445)
C_{17}	0.3838 (0.2200)	0.3945 (0.1497)	1.0454 (0.3814)
C_{37}	1.5146 (0.1869)	1.1181 (0.1075)	2.1055 (0.2304)
C_{57}	0.9513 (0.1620)	0.4839 (0.0763)	−1.8144 (0.2882)
C_{99}	0.0716 (0.0441)	1.4175 (1.9024)	−0.1615 (0.0593)

Note: This table reports the estimates of the elements of the 9 × 9 matrix $\mathbf{C}_S$, whose definition can be found in Appendix B. The figures in parentheses are the robust standard errors. $\mathbf{C}_S$ has seven unknown parameters. C_{ij} represents the element on the ith row and jth column of the matrix. The exchange rate equation is given by $\Delta\log S_t = \mathbf{z}_{t-1}'\mathbf{A}_1'\mathbf{B}_S\mathbf{A}_2\mathbf{z}_{t-1} + \mathbf{b}'\mathbf{z}_{t-1} + (\mathbf{C}_S\mathbf{z}_{t-1})'\boldsymbol{\varepsilon}_t$. Hence, $\mathbf{C}_S$ determines the conditional variance of $\Delta\ln S_t$,which can be obtained as $\mathrm{Var}_{t-1}(\Delta\log S_t) = \mathbf{z}_{t-1}'\mathbf{C}_S'\mathbf{C}_S\mathbf{z}_{t-1}$.

15. The estimated elements in $\mathbf{B}_S$ are reported in Table C1 in Appendix C.

$$i_t = a_1\varepsilon_{y,t} + a_2\varepsilon_{\pi,t} + a_3\varepsilon_{m,t} + a_4\varepsilon_{s,t}\,, \tag{15}$$

$$i_t^* = a_1^*\varepsilon_{y,t}^* + a_2^*\varepsilon_{\pi,t}^* + a_3^*\varepsilon_{m,t}^* + a_4^*\varepsilon_{s,t}\,, \tag{16}$$

where $\varepsilon_{y,t}$, $\varepsilon_{\pi,t}$, and $\varepsilon_{m,t}$ are exogenous shocks to the U.S. consumption growth, inflation, and monetary policy, respectively, while $\varepsilon_{y,t}^*$, $\varepsilon_{\pi,t}^*$, and $\varepsilon_{m,t}^*$ are exogenous shocks to the corresponding foreign variables. $\varepsilon_{s,t}$ is an exogenous innovation to the real exchange rate.[16] Table 2 reports the estimates of the contemporaneous policy reaction coefficients a_i and a_i^* ($i = 1,..., 4$).

Note that, unlike the usual monetary reaction function, both i_t and i_t^* in the above equations are the ex-post real interest rates, i.e.

$$i_t = \bar{i}_t - \pi_t\,,$$

$$i_t^* = \bar{i}_t^* - \pi_t^*\,,$$

where $\bar{i}_t$ and π_t are the nominal short-term interest rate and the rate of inflation, respectively, in the U.S., and $\bar{i}_t^*$ and π_t^* are the corresponding foreign variables.

From Table 2, we can see that in all cases except in Japan, the estimates of a_1 and a_1^* are positive and highly significant, indicating that the policy makers raise interest rates in response to positive innovations in consumption growth. The policy reactions to exogenous shocks to inflation need to be examined with care because

TABLE 2

Estimates of Monetary Policy Reaction Coefficients

	U.S. and Germany		U.S. and UK		U.S. and Japan	
	i_t	i_t^*	i_t	i_t^*	i_t	i_t^*
$\varepsilon_{y,t}$	3.5985		3.2418		2.2922	
	(0.8334)		(0.9486)		(0.5824)	
$\varepsilon_{\pi,t}$	−3.5481		−3.2276		−6.7962	
	(0.7383)		(0.6460)		(0.9396)	
$\varepsilon_{m,t}$	3.0904		2.5172		3.3539	
	(0.3946)		(0.2835)		(0.4183)	
$\varepsilon_{y,t}^*$		1.4934		5.0047		−1.4364
		(0.9392)		(1.8782)		(1.1912)
$\varepsilon_{\pi,t}^*$		−3.2714		−12.0673		−10.0580
		(0.9740)		(1.5322)		(1.3390)
$\varepsilon_{m,t}^*$		3.5071		3.6488		2.1443
		(0.5634)		(0.4700)		(0.3099)
$\varepsilon_{s,t}$	0.8022	−1.0837	0.6998	−0.4823	1.6478	1.4875
	(0.4501)	(0.4495)	(0.1610)	(0.2685)	(0.3633)	(0.2109)

Note: The reported figures are the estimates of the instantaneous reactions of the monetary policy instruments to various exogenous shocks in each country. The figures in parentheses are the robust standard errors. $\varepsilon_{y,t}$, $\varepsilon_{\pi,t}$, and $\varepsilon_{m,t}$ are exogenous shocks to the U.S. consumption growth, inflation, and monetary policy, respectively; $\varepsilon_{y,t}^*$, $\varepsilon_{\pi,t}^*$, and $\varepsilon_{m,t}^*$ are exogenous shocks to the corresponding foreign variables, and $\varepsilon_{s,t}$ is an exogenous shock to the real exchange rate. Abstracting from all lagged variables, the monetary policy reaction function is $i_t = a_1\varepsilon_{y,t} + a_2\varepsilon_{\pi,t} + a_3\varepsilon_{m,t} + a_4\varepsilon_{s,t}$ for the U.S. For the foreign country, the monetary policy reaction function is given by $i_t^* = a_1^*\varepsilon_{y,t}^* + a_2^*\varepsilon_{\pi,t}^* + a_3^*\varepsilon_{m,t}^* + a_4^*\varepsilon_{s,t}$. Both i_t and i_t^* are the ex-post real short-term interest rates (in one-tenth of a percentage point), i.e., $i_t = \bar{i}_i - \pi_t$ and $i_t^* = \bar{i}_t^* - \pi_t^*$ where $\bar{i}_t$ and $\bar{i}_t^*$ are the U.S. and foreign nominal interest rates and π and π_t^* are the rates of inflation.

16. We identify the policy response to the exchange rate shock based on the restriction that the U.S. (foreign) monetary policy only responds to the U.S. (foreign) output and inflation shocks. See the zero restrictions imposed on the last two rows of matrix **C** in Section 1.3.

$\varepsilon_{\pi,t}$ and $\varepsilon^*_{\pi,t}$ also have immediate impacts on π_t and π^*_t. Therefore, a negative estimate of a_2 or a^*_2 does not necessary imply that the central bank cuts its policy interest rate ($\bar{i}_t$ or $\bar{i}^*_t$) in response to a positive inflation shock. In fact, our estimates suggest that in almost all cases, the monetary authorities actually raise the nominal interest rate $\bar{i}_t$ or $\bar{i}^*_t$ in response to exogenous inflation shocks. In the U.S.–Germany case, for instance, as $\varepsilon_{\pi,t}$ or $\varepsilon^*_{\pi,t}$ increases by one unit, π_t or π^*_t increases by 5.2 or 6.1 units, respectively. Given the estimates of -3.5 for a_2 and -3.3 for a^*_2, they imply that both the U.S. and German central banks indeed push up the level of their policy instruments ($\bar{i}_t$ and $\bar{i}^*_t$) in response to exogenous inflation shocks.

In addition, the estimates of a_4 and a^*_4 might suggest that there are some contemporaneous monetary policy reactions to exogenous shocks to the real exchange rate. In particular, the positive estimates of a_4 imply that the Fed raises the short-term interest rate when the U.S. dollar depreciates in real terms against foreign currencies. Monetary authorities in Germany and Britain also respond to the innovations to the real exchange rate in a similar way, as indicated by the negative estimates of a^*_4.[17] It should be noted, however, that such an implication of the monetary policy response to the exchange rate is valid only under the maintained identification restriction that inflation does not respond immediately to the exchange rate shocks. Without this assumption, our model cannot rule out inflation-induced depreciation, and the estimates of a_4 and a^*_4 could simply reflect the policy response to inflation shocks. Moreover, we have assumed that the Fed does not respond to the foreign monetary shock ε^*_{mt} and the foreign central bank does not respond to the U.S. monetary shock ε_{mt} (see Equations (15) and (16) above). It is possible, however, that there are simultaneous policy interactions across countries. For example, the foreign central bank could respond to a positive U.S. monetary policy shock (a monetary tightening) by raising the foreign interest rate. Under this scenario, the U.S. dollar would appreciate against the foreign currency in response to the positive U.S. monetary policy shock. On the other hand, the foreign interest rate would also rise as a result of the foreign central bank's reaction to the U.S. monetary shock. Therefore, we would observe as if the foreign interest rate is responding to a depreciation of the foreign currency.

2.3 Variance Decomposition

Now we turn to the main result of this paper. As argued in Section 1.1 above, Equation (1) implies that we may use the movement of the real exchange rate ($-\Delta\log S_t$) to measure the difference in the marginal utility growth rates ($\log M_t - \log M^*_t$) between the domestic and foreign investors. If those international investors were able to achieve full risk sharing, $\log M_t$ would be equal to $\log M^*_t$ across every state of nature, and hence, we would obtain $\Delta\log S_t = 0$, i.e., the constant real exchange rate over time. In reality, the lack of complete markets and the existence of non-traded goods as well as transport costs most likely prevent

17. Note that a positive innovation $\varepsilon_{s,t}$ means a real depreciation of the U.S. currency and a real appreciation of the foreign currency.

international investors from fully sharing economic risks. When investors face a domestic shock that is difficult to diversify across national borders, the marginal utility growth ($\log M_t$) of the domestic investors would be driven apart from that of foreign investors $(\log M_t^*)$, leading to fluctuations in $\Delta\log S_t$. On the other hand, if a particular economic shock is perfectly shared by the domestic and foreign investors, $\log M_t$ and $\log M_t^*$ would move in lockstep in response to the shock, leaving $\Delta\log S_t$ unchanged. As a result, this shock would account for only a small portion of the volatility of the real exchange rate. Our structural VAR model enables us to examine which macroeconomic risks, each corresponding to a specific fundamental shock, are shared by international investors and which macroeconomic risks are not.

For the above purpose, we calculate a variance decomposition for $\Delta\log S_t$, which is treated as a proxy for $\log M_t^* - \log M_t$. For conventional linear VAR models, the variance decomposition can be obtained as a transformation of the model parameters. For nonlinear models, however, such a simple relation does not exist. Therefore, the variance decomposition is computed based on Monte Carlo simulations. Specifically, random shocks ($\varepsilon_{t+j}, j = 1,\ldots, 4$) are drawn and the four-quarter forecasting errors for $\Delta\log S_t$ are calculated from the estimated exchange rate equation. This process is repeated 500 times. The sample variances of the forecast errors due to each component of ε_{t+j} (namely, $\boldsymbol{\varepsilon}_{Y,t+j}$, $\boldsymbol{\varepsilon}_{\Pi,t+j}$, $\boldsymbol{\varepsilon}_{M,t+j}$, and $\boldsymbol{\varepsilon}_{S,t+j}$) are then computed. Since the variances are state-dependent due to the nonlinearity of the exchange rate movement, we first compute the variance decomposition conditional on each observation of $\mathbf{z}_t$ in our sample period (1973–96). We then take the average of the variances across different states. Table 3 reports those variances as percentages of the overall volatility of the forecast errors of $\Delta\log S_t$, or $\log M_t^* - \log M_t$, at each time horizon.[18]

TABLE 3

Variance Decomposition of $\Delta\ln S_t$

	Consumption Shock	Inflation Shock	Monetary Shock	Financial Shock
		First Quarter		
U.S./Germany	0.0315	0.4608	0.3079	0.1998
U.S./UK	0.0591	0.5983	0.2080	0.0884
U.S./Japan	0.1144	0.3683	0.3644	0.1530
		Fourth Quarter		
U.S./Germany	0.0512	0.6665	0.2764	0.0060
U.S./UK	0.1146	0.6847	0.1667	0.0340
U.S./Japan	0.1411	0.4794	0.3764	0.0031

Note: This table reports the results of variance decomposition for the movement of the real exchange rate, which approximates the U.S./foreign marginal utility growth differential. The VAR identification scheme assumes that consumption growth and inflation do not respond to financial shocks contemporaneously. Domestic (foreign) monetary policy feeds back only on the domestic (foreign) inflation and consumption growth, but they both feedback on the exchange rate. The same identification assumptions also apply to Table 4 where results of variance of decomposition for the stock returns are reported.

18. The variance decompositions are reported up to four quarters in Table 3. A longer horizon beyond four quarters yields no change in the main result.

The most striking finding from the above exercise is that exogenous financial shocks, the shocks to the exchange rate and stock market returns that are orthogonal to other macroeconomic shocks, jointly account for only a tiny fraction of the volatility of the U.S./foreign marginal utility growth differential ($\log M_t^* - \log M_t$). In the U.S./Germany case, the financial shocks jointly account for about 0.6% of the volatility of $\log M_t^* - \log M_t$ four quarters ahead. Similar results are found for other countries as well, more specifically 3.4% in the U.S./UK case and 0.3% in the U.S./Japan case. Almost all the variances of the marginal utility growth differentials are due to the exogenous shocks to consumption, inflation, and monetary policies.

To show that the identified financial shocks are indeed important sources of asset-market volatilities, we also compute the variance decomposition for the domestic and foreign stock returns, using the U.S./Germany, U.S./UK, and U.S./Japan data. The results are reported in Table 4. Across all countries, we find that the financial shocks in fact account for the largest share (25% and up) of the variance of stock market returns, a result in sharp contrast with the findings reported in Table 3, that the financial shocks appear to have little impact on the U.S./foreign marginal utility growth differentials. In the U.S./Germany case, the financial shocks jointly account for 28% and 36% of the volatility of the U.S. and German stock market returns, respectively. In the other two cases, the percentages are 65% and 61%, respectively, for the U.S. and British stock market returns, and 31% and 25%, respectively, for the U.S. and Japan stock market returns.

In summary, the results imply that while investors seem to be facing a significant amount of financial risks, these risks are diversified or shared very well across countries. The underlying financial shocks have little impact on the domestic/foreign marginal utility growth differentials. At the same time, however, these international investors do not appear to fully share other macroeconomic risks such as exogenous

TABLE 4

Variance Decomposition of Stock Returns

	Consumption Shock	Inflation Shock	Monetary Shock	Financial Shock
		First Quarter		
Germany	0.0336	0.2281	0.0962	0.6421
UK	0.0124	0.1973	0.0810	0.7094
Japan	0.0629	0.0861	0.0320	0.8190
U.S.[a]	0.0382	0.1305	0.0697	0.7617
U.S.[b]	0.0445	0.0799	0.0300	0.8456
U.S.[c]	0.0872	0.0006	0.0594	0.8527
		Fourth Quarter		
Germany	0.1872	0.2427	0.2064	0.3638
UK	0.0662	0.2086	0.1192	0.6060
Japan	0.2489	0.2491	0.2486	0.2534
U.S.[a]	0.2375	0.2427	0.2397	0.2802
U.S.[b]	0.1120	0.1354	0.1019	0.6508
U.S.[c]	0.2331	0.2246	0.2311	0.3112

Notes: [a]The results for the U.S. stock returns obtained from U.S./Germany country pair. [b]The results for the U.S. stock returns in U.S./UK country pair. [c]The results for the U.S. stock returns in U.S./Japan country pair.

shocks to consumption, inflation, and monetary policies, as each of these shocks contributes significantly to the volatility of the marginal utility growth differential across countries.

The above results are consistent with our knowledge about the incompleteness of financial markets. Full risk sharing through the existing financial markets requires that asset returns span the space of the underlying economic shocks, a proposition that is strongly rejected by empirical evidence (Davis, Nalwaik, and Willen 2000). For example, while labor earnings account for a major portion of national income, they are not securitized because of the non-marketable nature of human capital. Labor income in turn is shown to have near-zero correlation with aggregate equity returns (Fama and Schwert, 1977 and Botazzi, Pesenti, and Van Wincoop, 1996). On the other hand, aggregate supply and demand shocks as well as monetary policy shocks are likely to be most responsible for the uncertainties in labor income.

This lack of perfect risk sharing may also reflect the impact of non-traded consumption goods and transport costs, which can be affected significantly by shocks to aggregate consumption, inflation, and monetary policies. Suppose that a typical investor's utility function is characterized by non-separability between traded and non-traded consumption goods. The macroeconomic shocks would then drive the marginal utility growth of domestic investors away from that of foreign investors. As a result, there would be large fluctuations in the movement of the real exchange rate.

Brandt, Cochrane, and Santa-Clara (2001) obtain a strikingly different result from those in the previous studies of international risk sharing based on aggregate consumption. They show that there appear to be a lot of risks if one looks at asset-market data. The implied volatility of the marginal utility growth is very high. However, most of the risks seem to be shared very well by international investors, as measured by the implied correlation of the marginal utility growth rates across countries. On the other hand, the weak correlation of aggregate consumption growth rates among different countries as documented and analyzed in many previous studies seems to indicate very poor international risk sharing. The current paper does not intend to reconcile these two stylized facts. Our decomposition of risk, however, may provide one potential explanation of the apparently contradicting observations.

In particular, the results from our exercise suggest that if we only look at the aggregate consumption data,[19] we would overlook the fact that international investors share most of the financial market risks and conclude that risk sharing is poor across countries. On the other hand, if the exogenous financial market shocks are the most important source of risk that international investors face,[20] our results would lead to the same conclusion as in Brandt, Cochrane, and Santa-Clara (2001), that international investors share most of the risks they face.

19. Note that consumption growth is not the same as marginal utility growth unless the power utility function is assumed.

20. Note that our approach does not measure the relative magnitude of different macroeconomic risks since $\log M_t$ and $\log M_t^*$ are not separately observable, only their difference is.

2.4 Some Caveats

One caveat of our empirical exercise is the reliance on the movement of the real exchange rate ($\Delta\log\ S_t$) as a proxy of the marginal utility growth differential ($\log M_t - \log M_t^*$) across countries (the key equation is in Section 1.1). This implicitly makes strong assumptions about how investors behave in terms of their international portfolio decisions (such as rational expectations). Even if one resorts to a weaker assumption of no-arbitrage in international asset markets, Equation (1) will not hold for arbitrary pairs of domestic and foreign stochastic discount factors (M_t and M_t^*) if markets are incomplete.[21] In such a case, $\log M_t$ and $\log M_t^*$ in Equation (1) should be interpreted as the linear projection of the marginal utility growth onto the space of asset returns as pointed out by Brandt, Cochrane, and Santa-Clara (2001). Therefore, the movements of the real exchange rate may not be exactly linked to the fluctuations in the marginal utility growth differential. The movement of investors' marginal utility growth orthogonal to asset returns is not captured by our empirical model. For example, risk sharing can also be achieved through international government transfers and aids, rather than through financial markets. Our empirical exercise therefore only addresses the issue of what macroeconomic risks are or are not shared by international investors through the *existing* asset markets.

Another problem of the model is the use of aggregate consumption and aggregate stock market returns to identify the fundamental economic risks faced by investors. Recent research suggests that the uninsurable idiosyncratic consumption risk of individual investors can play a very important role in reconciling consumption-based asset-pricing models with stock returns (e.g., Constantinides, and Duffie 1996).[22] Using aggregate consumption, one ignores those risks and hence, could overestimate the amount of risk sharing across countries. On the other hand, most investors only hold stocks of a few individual firms, rather than the market portfolio. Using aggregate stock market returns, one ignores the possible reduction of systematic risk of individual firms (Chari and Henry 2002) and hence, could underestimate the amount of risk sharing among international investors.

In the case of limited participation in asset markets, the use of aggregate data could introduce yet another potential bias in our model, which treats the U.S. and other countries symmetrically in determining the market prices of risk (in particular, the third assumption used to identify $\mathbf{\Gamma}$ and $\mathbf{\Gamma}^*$ in Section 1.3). This is because the U.S. has probably a larger fraction of consumers who actually trade in financial markets than any other countries. Therefore, the aggregate consumption in the U.S. has less bias than the foreign one as a proxy of the consumption of the country's active investors, and hence, could affect the market prices of risk differently than the foreign consumption does. We address this issue in the next section.

21. Absence of arbitrage, however, is sufficient for the existence of the stochastic discount factors. See, for example, Harrison and Kreps (1979).

22. In fact the variance decomposition of stock returns indicates that there is a large portion of the variation in stock returns that is not "explained" by either aggregate consumption, inflation or monetary policy shocks in our empirical model. This may suggest the need to use disaggregated data to fully understand asset-market phenomena.

An attempt to fix these potential problems would require a carefully specified structural model. It is unlikely, however, that such an attempt would completely change the basic result about the *relative* degrees of international risk sharing in response to different kinds of economic shocks, as reported in Table 3. That is, compared to such macroeconomic risks as those associated with consumption, inflation, and monetary policy shocks, the risk associated with exogenous financial market shocks seems to be better diversified among international investors.

As in all VAR-based empirical studies, one crucial element of our model is the identification assumptions. In the next section, we check the sensitivity of the result to different identification schemes.

2.5 Alternative Identification Restrictions

Our VAR model postulates nine fundamental macroeconomic shocks, which we rewrite here for convenience

$$\boldsymbol{\varepsilon}_t = (\boldsymbol{\varepsilon}'_{Y,t}, \boldsymbol{\varepsilon}'_{\Pi,t}, \boldsymbol{\varepsilon}'_{M,t}, \boldsymbol{\varepsilon}'_{S,t})' = [(\boldsymbol{\varepsilon}_{y,t}, \boldsymbol{\varepsilon}^*_{y,t}), (\boldsymbol{\varepsilon}_{\pi,t}, \boldsymbol{\varepsilon}^*_{\pi,t}), (\boldsymbol{\varepsilon}_{m,t}, \boldsymbol{\varepsilon}^*_{m,t}), (\boldsymbol{\varepsilon}_{s,t}, \boldsymbol{\varepsilon}_{r,t}, \boldsymbol{\varepsilon}^*_{r,t})] \,.$$

In the current paper, we are not interested in identifying individual shocks included in $\boldsymbol{\varepsilon}_{\mathrm{t}}$ separately. Our focus, instead, is on the dynamic effects of the financial shocks $\boldsymbol{\varepsilon}_{S,t}$ as a group.

Our baseline model given in Section 1.3 allows unrestricted contemporaneous monetary response to a shock on the exchange rate, while not allowing monetary policy to respond to $\boldsymbol{\varepsilon}_{Y,t}$ and $\boldsymbol{\varepsilon}_{\Pi,t}$. One natural alternative to the baseline identification scheme is to disallow any contemporaneous reaction to a shock on the exchange rate, while relaxing all the restrictions on how monetary policy responds to consumption and inflation shocks ($\boldsymbol{\varepsilon}_{Y,t}$ and $\boldsymbol{\varepsilon}_{\Pi,t}$). This is a plausible assumption because it is unusual for central banks to systematically feedback on the foreign exchange rate or stock market returns.

One maintained assumption of the above two identification schemes is that neither consumption growth nor inflation responds contemporaneously to the financial shocks. It is possible, however, that movements in the foreign exchange rate may have an immediate impact on inflation, particularly when quarterly data are used. Therefore, the second alternative identification scheme we consider is the one that allows contemporaneous feedback of inflation (but not monetary policies) on the exchange rate shocks, while imposing restrictions on policy response to $\boldsymbol{\varepsilon}_{Y,t}$ and $\boldsymbol{\varepsilon}_{\Pi,t}$ similar to the baseline model. That is, the U.S. monetary policy only feeds back on the U.S. inflation shocks, but not on the foreign inflation shocks etc.

In our baseline model, the contemporaneous monetary response to the financial shocks $\boldsymbol{\varepsilon}_{S,t}$ is through the feedback of monetary policies on the foreign exchange rate. An alternative is through the feedback of monetary policies on the stock returns, rather than the exchange rate, though this seems less plausible than the baseline model. This is our third identification scheme.

We estimate our model under the above three alternative identification schemes. The results are reported in Panels A–C of Table 5. In most cases, we find the result qualitatively same as the one in our baseline model. That is, non-financial market risks (consumption, inflation, and monetary policy shocks) jointly account for almost the entire variance of the marginal utility growth differential across countries, and little is left for the exogenous financial shocks. These calculations confirm that our earlier conclusion about relative risk sharing is not sensitive to different identification restrictions on the structural shocks.

It should be noted that the various identification schemes discussed above focus on isolating the exogenous financial market shocks as a group from the remaining macroeconomic shocks. Therefore, the interpretation of the results regarding the individual component of the non-financial market shocks should proceed with care. For example, our results seem to suggest that the inflation shock accounts for a significant portion of the volatility of the marginal utility growth differential across countries (see Table 3). This result could reflect the effects of nominal rigidities. It also could reflect the impact of unanticipated inflation on the real burden of household

TABLE 5

Variance Decomposition of $\Delta \ln S_t$

A. Identification Scheme: Recursive

	Consumption Shock	Inflation Shock	Monetary Shock	Financial Shock
		First Quarter		
U.S./Germany	0.0218	0.4157	0.3161	0.2464
U.S./UK	0.1065	0.3747	0.1844	0.3344
U.S./Japan	0.0851	0.3214	0.3664	0.2471
		Fourth Quarter		
U.S./Germany	0.0345	0.5320	0.4294	0.0040
U.S./UK	0.1818	0.5460	0.2497	0.0225
U.S./Japan	0.1008	0.4211	0.4761	0.0020

B. Identification Scheme: Inflation Feeds Back on the Exchange Rate

	Consumption Shock	Inflation Shock	Monetary Shock	Financial Shock
		First Quarter		
U.S./Germany	0.0318	0.6246	0.3156	0.0280
U.S./UK	0.0432	0.5158	0.2014	0.2396
U.S./Japan	0.4350	0.0485	0.4272	0.0892
		Fourth Quarter		
U.S./Germany	0.1426	0.4611	0.2551	0.1411
U.S./UK	0.0331	0.8723	0.0601	0.0344
U.S./Japan	0.8319	0.1037	0.0574	0.0070

C. Identification Scheme: Monetary Policy Feeds Back on Stock Returns

	Consumption Shock	Inflation Shock	Monetary Shock	Financial Shock
		First Quarter		
U.S./Germany	0.0351	0.2945	0.4609	0.2095
U.S./UK	0.0068	0.2701	0.3738	0.3493
U.S./Japan	0.1761	0.0147	0.6294	0.1798
		Fourth Quarter		
U.S./Germany	0.0441	0.3941	0.5578	0.0039
U.S./UK	0.0267	0.4036	0.5442	0.0255
U.S./Japan	0.2475	0.0082	0.7376	0.0068

debt. The impact of the inflation shock varies, however, depending on alternative identification schemes and different country pairs (see Table 5). This suggests that the identified inflation shock might also pick up the impact of other non-financial market risks such as the consumption shock. It is more appropriate to treat all the non-financial market shocks as a group when interpreting the results of the current paper.

As noted in the last section, our model also makes assumptions to identify the parameters in the market prices of risk in addition to those necessary for identifying the structural shocks. In particular, we made an assumption that the impact of the U.S. consumption on the market price of foreign consumption risk is equal in size to the impact of the foreign consumption on the market price of the U.S. consumption risk, and so on. Under an alternative identification scheme, we relax this restriction and allow those impacts to be different across countries. In other words, the off-diagonal elements (C_{12}, C_{34}, C_{56}, and C_{89}) of matrix $\mathbf{C}_S$ are no longer restricted to be zero to reflect this kind of symmetry.[23] We then estimate the model under this new assumption about $\mathbf{\Gamma}$ and $\mathbf{\Gamma}^*$ in combination with the four different identification schemes for the structural shocks (i.e., the baseline model plus the above three different sets of restrictions on $\boldsymbol{\varepsilon}_t$). The results for the baseline case are reported in Tables 6 and 7. Table 6 includes the estimates of the parameters in matrix $\mathbf{C}_S$ (see Appendix B for the definition of $\mathbf{C}_S$) and Table 7 reports the results of variance decomposition for the movement of the real exchange rate.[24]

As we can see from Table 6, many of the estimates of the off-diagonal elements (C_{12}, C_{34}, C_{56}, and C_{89}) of $\mathbf{C}_S$ are statistically significant and economically important. Moreover, the results also seem to vary a lot across the three country pairs. Similar

TABLE 6

ALTERNATIVE ESTIMATES OF THE MATRIX $\mathbf{C}_S$

	U.S./Germany Ex-Rate	U.S./UK Ex-Rate	U.S./Japan Ex-Rate
C_{12}	–1.6396 (0.4389)	0.0212 (0.4446)	0.0799 (2.0948)
C_{34}	–0.5108 (0.4435)	0.5101 (0.3081)	–2.0522 (2.6659)
C_{56}	4.8518 (1.0103)	–2.0989 (0.3687)	0.5273 (2.0245)
C_{17}	–0.3184 (0.3503)	0.4759 (0.1672)	3.5347 (1.2964)
C_{37}	0.8920 (0.2047)	1.1725 (0.1041)	4.0031 (0.9731)
C_{57}	1.7892 (0.2046)	0.4911 (0.0897)	1.7634 (0.5258)
C_{89}	0.3610 (0.0825)	0.0256 (0.0457)	–0.4550 (0.1827)

NOTE: This table reports the estimates of the elements of the 9 × 9 matrix $\mathbf{C}_S$, whose definition can be found in Appendix B. The figures in parentheses are the robust standard errors. The identification assumption is that the impact of y_t on the market price of the U.S. consumption risk is the same as the impact of y_t^* on the market price of the foreign consumption risk. In the meantime, we allow that the impact of y_t on the market price of the *foreign* consumption risk to be different from the impact of y_t^* on the market price of the U.S. consumption risk. $\mathbf{C}_S$ has seven unknown parameters. C_{ij} represents the element on the *i*th row and *j*th column of the matrix. The exchange rate equation is given by $\Delta \log S_t = \mathbf{z}'_{t-1}\mathbf{A}'_1\mathbf{B}_S\mathbf{A}_2\mathbf{z}_{t-1} + \mathbf{b}'\mathbf{z}_{t-1} + (\mathbf{C}_S\mathbf{z}_{t-1})'\boldsymbol{\varepsilon}_t$.

23. Since the model is just identified, we need, however, to assume that the impact of the U.S. consumption on the market price of the *U.S.* consumption risk is equal in size to the impact of the foreign consumption on the market price of the *foreign* consumption risk, which makes the diagonal elements (C_{11}, C_{33}, C_{55}, and C_{99}) of $\mathbf{C}_S$ zero. See Appendix B for details.

24. The results for other cases are not reported here due to space limitation, but are available upon request. The major result remains the same in all cases.

TABLE 7

VARIANCE DECOMPOSITION OF $\Delta \ln S_t$ UNDER ALTERNATIVE IDENTIFICATION SCHEME FOR $\mathbf{C}_S$

	Consumption Shock	Inflation Shock	Monetary Shock	Financial Shock
		First Quarter		
U.S./Germany	0.0566	0.1415	0.6376	0.1642
U.S./UK	0.0740	0.4241	0.2103	0.2917
U.S./Japan	0.2835	0.3673	0.0709	0.2783
		Fourth Quarter		
U.S./Germany	0.0280	0.2157	0.7522	0.0040
U.S./UK	0.1439	0.6704	0.1535	0.0321
U.S./Japan	0.3847	0.5042	0.1099	0.0012

NOTE: This table reports the results for variance decomposition for the movement of the real exchange rate, which approximates the U.S./foreign marginal utility growth differential. The identification restrictions for the structural shocks ε_t are the same as those in the baseline case. However, we impose the alternative restriction on the matrix $\mathbf{C}_S$ as discussed in Section 2.5. The results for all other cases are available upon request.

results are obtained for all other cases. This suggests not only that the impacts of the U.S. and foreign macro variables on the risk premiums are likely different, but also that the degree of asymmetry varies across countries. Nevertheless, the main result regarding the relative risk sharing remains the same under this alternative identification scheme for $\mathbf{C}_S$, as shown in Table 7. In fact, for the three country pairs, the exogenous financial shocks still account for the smallest fraction of the variance of the marginal utility growth differential among all the shocks identified by our VAR.

3. CONCLUDING REMARKS

International risk sharing has been an important research topic in international macroeconomics and finance. While most of the previous studies have focused on the degree of international risk sharing, the current paper identifies various macroeconomic risks faced by investors and asks whether some risks are better diversified than others internationally.

Taking an asset-pricing approach, we found that international investors share most of the risks of exogenous financial market shocks. However, other macroeconomic risks such as those associated with exogenous shocks to consumption growth, inflation, and monetary policies are not fully shared across countries. This asset-market-based approach to international risk sharing allowed us to avoid the possibility of making too stringent an assumption of the utility function as well as the difficult task of distinguishing and measuring traded and non-traded consumption goods and transport costs. The empirical exercise helped us understand the apparently contradicting pictures of international risk sharing painted by asset-market returns and by aggregate consumption growth across countries.

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