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A Reexamination of *Ex Ante* Pricing of Currency Risk in the Japanese Stock Market: A Pricing Kernel Approach

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Abstract

This paper attempts to reexamine *ex ante* pricing of currency risk in the Japanese stock market within a framework of the conditional Arbitrage Pricing Theory (APT), which has time-varying pricing coefficients of potential risk factors including market return, long-term interest rate, and the foreign exchange rate. In addition to the ordinary GMM estimation of pricing coefficients, special emphasis is given to diagnostic tests on the validity of implied series of stochastic discount factors (pricing kernels). Empirical results show that when foreign exchange risk is included in the model, a good performance is recorded in terms of the GMM estimation, but the implied series of stochastic discount factors almost always violates the required restrictions, such as the non-negativity restriction and Hansen and Jagannathan's (1991) volatility bound restriction. It turns out that the specification with market return as the sole risk factor performs best in terms of those diagnostic tests.

Key words: Currency Risk; Asset Pricing; Volatility Bound Test;
GMM; Stochastic Discount Factor; Arbitrage Pricing Theory

JEL classification: F31; G12

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I. Introduction

Since the transition to a floating exchange rate regime, currency risk has been one of the major sources of concern for multinational corporations and they have devoted substantial resources to the management of currency risk.

As emphasized by Adler and Dumas (1983), however, if one assumes that all the conditions of the Modigliani and Miller (1958) propositions hold, the capital budgeting criterion has nothing to do with the choice of measurement currency, the nationality of the firm, and other financial decisions. Hence, if such a world existed, any owners of firms would not necessarily have an incentive to manage their currency risk exposure.

So why are multinationals so actively engaged in risk management? As suggested by Jorion (1991)[1], one of the potential (but, often overlooked) explanations is that hedging is valuable to stock market investors because currency risk is priced *ex ante* in the stock market, which means that currency hedging could change the cost of capital for the firm. This is due to the fact that an expected stock return can be defined as the market price of the risk factor times the exposure coefficient, which is shown by Adler and Dumas (1983). So if firms can effectively control their currency risk exposure using hedging instruments, they can influence expected returns on their equities, given the market price of currency risk.

This proposition can be directly tested by the Arbitrage Pricing Theory (APT). The APT pioneered by Ross (1976, 1983) states that if the economy can be described in terms of a small number of risk factors, then these factors might be priced *ex ante* in the sense that investors would be willing to pay or demand a premium to avoid these

[1] He examined *ex ante* pricing of currency risk within a context of the unconditional multiple-factor APT, which assumes constant prices of risk factors. His finding basically rejects the hypothesis of *ex ante* pricing of currency risk.

sources of risk. In this framework, hedging policies can affect the cost of capital if and only if the innovation of the foreign exchange rate is included in those factors.

As for empirical methodologies, there are two variants of the APT: unconditional and conditional versions. An unconditional version of the APT treats each pricing coefficient of risk factors as a constant term under the implicit assumption that the information set available to investors is stationary. In contrast, a conditional version of the APT assumes a time-varying market price of each risk factor, which is conditional on the information set within a framework of intertemporal Euler equations. Hence, the unconditional APT can be viewed as a special case of the conditional APT.

The pricing coefficients of potential risk factors of the conditional APT can be estimated by Hansen's (1982) generalized method of moments (GMM). In the preceding literature, Dumas and Solnik (1995) showed that a conditional international asset pricing model with the foreign exchange rate as one of the risk factors outperforms the unconditional model used in prior studies such as Jorion (1991) and Hamao (1988), concluding that currency risk is priced for stock markets of the four major countries (Germany, UK, Japan, and U.S.).

Dumas and Solnik used indices of national stock returns instead of disaggregated stock returns since they explored whether or not the world capital market is integrated as a whole. However, it is important to examine, for example, the industry-level data, particularly in Japan, where some industries are highly dependent on international trade and so an exchange rate shock is likely to have a big impact on the stock returns on those industries.

Quite recently, Choi, Hiraki, and Takezawa (1998) tested whether or not currency risk is priced *ex ante* within the same framework as Dumas and Solnik's, but they did so by using industry-level Japanese stock market data. After conducting some hypothesis testing based solely on the GMM estimation, they concluded that currency risk is priced *ex ante* in the Japanese stock market[2].

A large literature on asset pricing, however, has pointed out the importance of examining properties of stochastic discount factors (pricing kernels) implied by asset-pricing models. First, they should possess a positive value throughout the sample period, since a stochastic discount factor is originally defined as the discount rate times the ratio of the marginal utility of consumption in the next period to that of consumption in the current period.

Second, as suggested by Hansen and Jagannathan (1991), means and variances of stochastic discount factors should lie within a region that is consistent with a given set of asset return data, which is called the volatility bounds test.

Third, means of stochastic discount factors should be consistent with the means of both the risk-free and risky asset returns. In other words, the true stochastic discount factor should price any returns properly in order for Euler equations to hold[3]. This condition is closely related to the so-called risk-free rate and equity premium puzzles first proposed by Mehra and Prescott (1985).

Motivated by the above discussion, this paper attempts to reexamine whether or not currency risk is priced *ex ante* in the Japanese stock market using industry-level data within the same framework as in Dumas and Solnik (1995). In this paper, however, much more attention is paid to diagnostic tests on the implied series of stochastic discount factors than was the case in preceding studies.

The rest of the paper is organized as follows. Section II describes the theoretical background of the conditional APT and the estimation strategy. In Section III, diagnostic tests of the implied series of stochastic discount factors are explained.

[2] Also, Doukas, Hall, and Lang (1999) apply an intertemporal asset pricing model that allows risk premia to change through time, and show that foreign exchange risk premium is a significant component of Japanese stock returns. However, they do not investigate the restrictions that the implied series of the stochastic discount factor should satisfy.

Section IV gives a description of the data. Section V presents empirical results and Section VI concludes this paper.

II. The Conditional APT: Theory and Estimation Strategy

(i) Theoretical Background

Following Dumas and Solnik (1995), let me assume that the *i* th asset's expected return in excess of the risk-free interest rate $R^f_{t,t+1}$ from time *t* to time *t*+1, $E[R^i_{t,t+1} - R^f_{t,t+1} \mid \Omega_t]$, is conditional on an information set Ω_t, which is available to every investor at the start of time *t*. Here the *k*-factor conditional asset pricing model for portfolio *i* can be written as

$$E[R^i_{t,t+1} - R^f_{t,t+1} \mid \Omega_t] = \sum_k \gamma^k(\Omega_t) Cov[R^i_{t,t+1} - R^f_{t,t+1}, R^k_{t,t+1} \mid \Omega_t], \tag{1}$$

where $Cov[R^i_{t,t+1} - R^f_{t,t+1}, R^k_{t,t+1} \mid \Omega_t]$ is the covariance between the excess return of the *i* th asset and the *k* th risk factor $R^k_{t,t+1}$, and $\gamma^k_t \equiv \gamma^k(\Omega_t)$ is the time-varying price of the *k* th risk factor. These values are conditional on the information set Ω_t[4].

A large volume of literature on the Arbitrage Pricing Theory (APT) proposes a two-factor model with the market return and the interest rate as its risk factors[5]. To my knowledge, inclusion of the currency risk factor in this kind of asset pricing model was first proposed by Adler and Dumas (1983), and later examined by Jorion (1991), Bodner and Gentry (1993), Choi and Prassad (1995) and others. Moreover, Choi, Elyasiani and Kopecky (1992) and Prasad and Rajan (1995) use the interest rate and the

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[3] In this paper, let me call this a mispricing test.

[4] Ross's (1976) unconditional APT implies that $E\left[R^i_{t,t+1} - R^f_{t,t+1}\right] = \sum_k \delta^k \beta^i_k$, where δ^k indicates the market price of the *k*-th risk factor, while β^i_k captures the sensitivity of the *i*-th return to the *k*-th risk factor. Note that equation (1) is the same as Ross's APT if the information set is stationary, that is, $\Omega_t = \Omega$ for all time *t*. More specifically, the set of conditions $\delta^k = \gamma^k[Var(R^k_{t,t+1})]$ for every *k* assures that equation (1) is equivalent to Ross's APT in the case in which $\Omega_t = \Omega$ for all time t.

[5] For example, see Stone (1974), Eddy (1978), and Gultekin and Rogalski (1985).

foreign exchange rate in addition to the market return as risk factors to construct a multiple-factor model[6].

Motivated by the above-mentioned literature, the following versions of the APT will be studied in this paper. The first one is a one-factor model, which has a market return in excess of the risk-free interest rate, foreign exchange rate, or interest rate as a sole risk factor. The second one is a two-factor model, which has any combination of two of those factors, and the third one is a three-factor model, which has all these variables as risk factors.

Before proceeding to the estimation strategy, let me state the first-order Euler conditions for a general intertemporal portfolio choice in order to clarify the relationship between the stochastic discount factor and the market price of each potential risk factor:

$$E[M_{t,t+1} R^f_{t,t+1} \mid \Omega_t] = 1, \tag{2}$$

and $$E[M_{t,t+1} R^i_{t,t+1} \mid \Omega_t] = 1 \qquad \text{for } i=1,\ldots n \text{ th risky asset.} \tag{3}$$

And condition (3) is often replaced by

$$E[M_{t,t+1}\left(R^i_{t,t+1} - R^f_{t,t+1}\right) \mid \Omega_t] = 0 \qquad \text{for } i=1,\ldots n \text{ th risky asset,} \tag{4}$$

where $M_{t,t+1}$[7] denotes the conditional marginal rate of substitution from time t to time $t+1$, which is usually called the stochastic discount factor or the pricing kernel.

In words of Ferson (1995), any asset-pricing model can be described as a particular application of $M_{t,t+1}$. It turns out that the model (1) specifies $M_{t,t+1}$ to be the following form:

$$M_{t,t+1} = \frac{1}{R^f_{t,t+1}}\left[1 - \gamma^0_t - \sum_k \gamma^k_t R^k_{t,t+1}\right], \tag{5}$$

[6] But it should be noted that all the models they examine are unconditional ones.

[7] In a typical intertemporal maximization problem, $M_{t,t+1}$ is defined as $\beta u'(C_{t+1})/u'(C_t)$, where β is a constant time-discount rate and $u'(C)$ is the marginal utility of consumption.

where a new time-varying term γ_t^0 appears as a way of ensuring that equation (2) is satisfied[8]. Using equation (5) enables us to rewrite Euler equations (2) and (4) as follows:

$$E\left[\left(1-\gamma_t^0-\sum_k \gamma_t^k R_{t,t+1}^k\right) \mid \Omega_t\right]=1, \tag{6}$$

and $$E\left[\left(1-\gamma_t^0-\sum_k \gamma_t^k R_{t,t+1}^k\right)\frac{R_{t,t+1}^i-R_{t,t+1}^f}{R_{t,t+1}^f} \mid \Omega_t\right]=0 \qquad \text{for } i=1,\ldots n \text{ th risky asset.} \tag{7}$$

Here, it should be noted that an expression for the excess return can be written as

$$\begin{aligned} E\left[R_{t,t+1}^i-R_{t,t+1}^f \mid \Omega_t\right] &= -E\left[R_{t,t+1}^i \mid \Omega_t\right]Cov\left[R_{t,t+1}^i, M_{t,t+1} \mid \Omega_t\right] \\ &= E\left[R_{t,t+1}^i \mid \Omega_t\right]Cov\left[R_{t,t+1}^i, \frac{1}{R_{t,t+1}^f}\left(1-\gamma_t^0-\sum_k \gamma_t^k R_{t,t+1}^k\right) \mid \Omega_t\right], \end{aligned} \tag{8}$$

which reveals that an asset's expected return is greater, the smaller its covariance with the stochastic discount factor $M_{t,t+1}$.

(ii) The GMM Estimation Strategy

Next, let me specify how market prices γ_t^k s change over time. In a general equilibrium setting, they would probably be nonlinear functions of numerous exogenous variables describing the economy[9]. Nonetheless, for simplicity, let me assume that the risk prices γ_t^k s and γ_t^0 are linearly related to the instrumental variables such that

$$\gamma_t^0=-\mathbf{Z}_t\Phi^0 \text{ and } \gamma_t^k=\mathbf{Z}_t\Phi^k, \tag{9}$$

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[8] γ_t^0 is not actually a market price of risk, but a pure reflection of the current level of the risk-free interest rate $R_{t,t+1}^f$ compared to the current level of the risk premium. From equation (6), one knows the following relationship: $E\left[\gamma_t^0 \mid \Omega_t\right]=E\left[\sum_k \gamma_t^k R_{t,t+1}^k \mid \Omega_t\right]$.

[9] Bansal, Hsieh, and Viswanathan (1993) apply non-linear pricing kernels to international returns. Their method directly characterize the stochastic discount factor as a linear combination of the instrumental variables by omitting the existence of risk factors such that $M_{t,t+1}=a_0+\sum_l a_1^l Z_t^l+\sum_i a_2^l\left(Z_t^l\right)^2+\ldots$, where Z_t^l is the l th instrumental variable. Thus, it cannot determine which risk factor is priced and which is not. I tried a quadratic specification instead of linear equations (9), but its performance was generally worse than the linear specification. So, I follow the linear specification of Dumas and Solnik (1995).

where Φ s are constant column vectors to be estimated by the GMM and $\mathbf{Z}_t$ is a row vector of l predetermined instrumental variables as a proxy for Ω_t. Now define the innovation u_{t+1} such that

$$u_{t+1} = 1 - M_{t,t+1} R^f_{t,t+1} . \tag{10}$$

The definition (5) of $M_{t,t+1}$ and the set of equations (9) enable us to get

$$u_{t+1} = -\mathbf{Z}_t \Phi^0 + \sum_k \mathbf{Z}_t \Phi^k R^k_{t,t+1} , \tag{11}$$

where u_{t+1} satisfies

$$E[u_{t+1} \mid \Omega_t] = 0 , \tag{12}$$

due to equation (2). Next define h^j_{t+1} such that

$$h^j_{t+1} \equiv \left(R^j_{t,t+1} - R^f_{t,t+1}\right) - \left(R^j_{t,t+1} - R^f_{t,t+1}\right) u_{t+1} = \left(R^j_{t,t+1} - R^f_{t,t+1}\right) M_{t,t+1} R^f_{t,t+1} . \tag{13}$$

Here Equation (4) implies that

$$E[h^j_{t+1} \mid \Omega_t] = E\left[\left(R^j_{t,t+1} - R^f_{t,t+1}\right) M_{t,t+1} R^f_{t,t+1} \mid \Omega_t\right] = R^f_{t,t+1} E\left[\left(R^j_{t,t+1} - R^f_{t,t+1}\right) M_{t,t+1} \mid \Omega_t\right] = 0 . \tag{14}$$

Moreover, let me form the $1+n$ vector of residuals such that $\mathbf{e}_{t+1} = (u_{t+1}, \mathbf{h}_{t+1})$, where $\mathbf{h}_{t+1}$ denotes the vector of h^j_{t+1} for all j. By construction, equations (12) and (13) yield

$$E[\mathbf{e}_{t+1} \mid \Omega_t] = 0 . \tag{15}$$

Now, define the NxR dimensional vector $\mathbf{g}_{t+1}$ such that $\mathbf{g}_{t+1} = \mathbf{e}_{t+1} \otimes \mathbf{Z}_t$, where $\otimes$ denotes the Kronecker product. By the law of iterated expectation, it follows that

$$E(\mathbf{g}_{t+1}) = E[E(\mathbf{g}_{t+1} \mid \Omega_t)] = E[E(\mathbf{e}_{t+1} \otimes \mathbf{Z}_t \mid \Omega_t)] = E[E(\mathbf{e}_{t+1} \mid \Omega_t) \otimes \mathbf{Z}_t] = 0 . \tag{16}$$

Thus, the following condition should hold:

$$E[\mathbf{e}_{t+1} \otimes \mathbf{Z}_t] = 0 . \tag{17}$$

This is the orthogonality condition used in the GMM framework. Further, let me define the sample average of $\mathbf{g}_t$ as

$$\overline{\mathbf{g}}_T = \frac{1}{T} \sum_{t=1}^{T} \mathbf{g}_t . \tag{18}$$

Under this setting, in a general form, the GMM estimate of $\hat{\theta}$ can be obtained by

$$\hat{\theta} = arg\ \underset{\theta}{max}\ \bar{\mathbf{g}}_T{}'\mathbf{W}_T\ \bar{\mathbf{g}}_T\ , \tag{19}$$

where $\mathbf{W}_T$ denotes the weight matrix. Hansen (1982) shows that if one chooses a consistent estimate of the covariance matrix of the sample pricing errors $\bar{\mathbf{g}}_T$ as $\mathbf{W}_T$, the GMM estimator is optimal in the sense that the variance matrix is as small as possible.

Here, equation (15) can be expressed as $E[f(\mathbf{x}_t, \omega \mid \Omega_t)] = 0$, where $\omega = (\Phi^0, \Phi^k{}')$ is a combined vector of coefficients to be estimated and $\mathbf{x}_t$ represents the data on asset returns and potential risk factors. Now the asymptotic covariance matrix of the vector $\sqrt{T}(\hat{\omega} - \omega_0)$ is given by

$$\mathbf{Var}(\hat{\xi}) = (\mathbf{D}_0'\mathbf{S}_0^{-1}\mathbf{D}_0)^{-1}\ , \tag{20}$$

where $\mathbf{S}_0 = \sum_{i=-\infty}^{\infty} Ef(\mathbf{x}_t, \omega_0 \mid \Omega_t) f(\mathbf{x}_t, \omega_0 \mid \Omega_t)'$ and $\mathbf{D}_0 = E\dfrac{\partial f(\mathbf{x}_t, \omega_0 \mid \Omega_t)}{\partial \omega}$. (21)

In practice, these values are estimated by

$$\mathbf{Var}(\hat{\omega}) = (\mathbf{D}_T'\mathbf{S}_T^{-1}\mathbf{D}_T)^{-1}\ , \tag{22}$$

where
$$\begin{aligned}\mathbf{S}_T = {} & \frac{1}{T}\sum_{t=1}^{T} f(\mathbf{x}_t, \hat{\omega} \mid \Omega_t) f(\mathbf{x}_t, \hat{\omega} \mid \Omega_t)' + \sum_{i=1}^{n}\left[1 - \frac{i}{n+1}\right] \\ & \times \left[\frac{1}{T}\sum_{t=1+i}^{T} f(\mathbf{x}_t, \hat{\omega} \mid \Omega_t) f(\mathbf{x}_{t-i}, \hat{\omega} \mid \Omega_t)' + \frac{1}{T}\sum_{t=1}^{T-i} f(\mathbf{x}_t, \hat{\omega} \mid \Omega_t) f(\mathbf{x}_{t+i}, \omega \mid \Omega_t)'\right],\end{aligned} \tag{23}$$

and
$$\mathbf{D}_T = \frac{1}{T}\sum_{t=1}^{T}\frac{\partial f(\mathbf{x}_t, \hat{\omega} \mid \Omega_t)}{\partial \omega}\ . \tag{24}$$

This method of estimating $\mathbf{S}_T$ is due to Newey and West (1987). Throughout this paper, n=12 is used. When the number of orthogonality conditions exceeds the number of parameters to be estimated, the model is overidentified in that more orthogonality conditions are used than are needed for actual estimation. In this regard, Hansen (1982) has shown that the minimized value of the quadratic form $\bar{\mathbf{g}}_T{}'\mathbf{W}_T\ \bar{\mathbf{g}}_T$ times the number of observations T, called the *J*-statistic, is χ^2 distributed under the null hypothesis that the model is properly specified with the degree of freedom that is equal to the number of orthogonality conditions net of the number of parameters to be estimated. In plain words, the *J*-statistic tests whether the estimated error of the investor's forecast is uncorrelated with any of the instrumental variable in the information set available at the time of the forecast. Intuitively, a high value of this statistic indicates a high probability that the model is misspecified[10].

In order to estimate the model, one needs to specify the instrumental variables that consist of the information set Ω_t. As pointed out by many authors, one of the major shortcomings of any asset-pricing model is that the model itself can not provide any guidance as to the choice of instrumental variables.

Regarding this point, this paper aims to explore the behavior of stock market returns using "economically meaningful" variables. According to Harvey (1994), expected stock returns are influenced by expected real activity[11]. Hence, variables that forecast real activity should also forecast stock returns. Well-known examples are default risk premium and term structure. Also, the role of "macro" variables such as an innovation of an aggregate production and surprise (unexpected) inflation is of great interest to researchers[12], as is emphasized by traditional macroeconomics.

Thus, in this paper, let me pick up the following four economic variables: the growth rate of industrial production (IP), unexpected inflation (UI), default risk premium (UPR), and term structure (UTS)[13]. Of these four variables, IP and UI have a so-called aggregation problem in the sense that release of these data is delayed by about two months, while any investor can get almost real-time information about UPR and UTS. Hence the following two sets of instrumental variables: Z1, which includes all

[10] Unfortunately, however, as shown by Newey (1985), Hansen's *J*-statistic can easily fail to detect a misspecified model. It is therefore often advisable to supplement this test with others.
[11] See Fama (1981, 1990).
[12] For example, Chen, Roll, and Ross (1986) investigate the relationship between stock returns and these variables in the U.S.
[13] UPR is defined as the interest rate differential between the corporate bond and the long-term government bond. UTS is defined as the difference between the long-term government bond

these four variables (IP and UI are lagged by two months) plus a constant, and Z2, which includes only UPR and UTS, as well as a constant[14].

(iii) Hypothesis Testing (Wald Test) on the Pricing Coefficients

This paper also tries to test various restrictions using the Wald test. Let me first examine the null hypothesis that all Φ_j^k coefficients of instrumental variables are zero with respect to a particular risk factor k . Secondly I check whether the price of each risk factor is time-varying or not by retaining only a time-invariant constant $\Phi_{Constant}^k$ and at the same time restricting all other Φ_j^k coefficients that create the time-varying prices of risks to be zero with respect to a particular risk factor *k*. Finally I test the null hypothesis that the Φ_j^k coefficients of all instrumental variables across all risk factors are jointly zero.

Each null hypothesis can be expressed as

(i) (Z1) $\Phi_{Constant}^k = \Phi_{IP}^k = \Phi_{UI}^k = \Phi_{UPR}^k = \Phi_{UTS}^k = 0$ for *k*=0, MKT, EX, or INT (25)

(Z2) $\Phi_{Constant}^k = \Phi_{UPR}^k = \Phi_{UTS}^k = 0$ for *k*=0, MKT, EX, or INT (26)

(ii) (Z1) $\Phi_{IP}^k = \Phi_{UI}^k = \Phi_{UPR}^k = \Phi_{UTS}^k = 0$ for *k*=0, MKT, EX, or INT (27)

(Z2) $\Phi_{UPR}^k = \Phi_{UTS}^k = 0$ for *k*=0, MKT, EX, or INT (28)

(iii)(Z1) $\Phi_{IP}^k = \Phi_{UI}^k = \Phi_{UPR}^k = \Phi_{UTS}^k = 0$ for all *k* (29)

(Z2) $\Phi_{UPR}^k = \Phi_{UTS}^k = 0$ for all *k*, (30)

where

$$\text{(Z1)}\quad \gamma_t^0 = -\left(\Phi_{Constant}^0 + \Phi_{IP}^0 IP_{t-2} + \Phi_{UI}^0 UI_{t-2} + \Phi_{UPR}^0 UPR_t + \Phi_{UTS}^0 UTS_t\right) \tag{31}$$

interest rate and collateralized overnight call rate. As discussed later, construction of UI follows the Fama and Gibbons' (1982, 84) methodology.

[14] Dumas and Solnik (1995) and Choi, Hiraki, and Takezawa (1998) include a January dummy variable in a list of instrumental variables. But, as suggested by Dumas and Solnik (1995), in Japan, the fiscal year ends in March, so there might be a case for introducing an April dummy variable instead of a January one. In order to avoid this kind of arbitrariness, I exclude any seasonal dummy variables by using seasonal (and also trading-day effects)-adjusted data.

$$\gamma_t^k = \Phi_{Constant}^k + \Phi_{IP}^k IP_{t-2} + \Phi_{UI}^k UI_{t-2} + \Phi_{UPR}^k UPR_t + \Phi_{UTS}^k UTS_t \tag{32}$$

for k=MKT, EX, or INT

(Z2) $$\gamma_t^0 = -\left(\Phi_{Constant}^0 + \Phi_{UPR}^0 UPR_t + \Phi_{UTS}^0 UTS_t\right) \tag{33}$$

$$\gamma_t^k = \Phi_{Constant}^k + \Phi_{UPR}^k UPR_t + \Phi_{UTS}^k UTS_t \qquad \text{for } k\text{=MKT, EX, or INT.} \tag{34}$$

It should be noted here that the likelihood ratio (LR) test, the Lagrange multiplier (LM) test, and the Wald test are asymptotically equivalent[15], but they can behave rather differently in a small sample. Unfortunately, their small-sample properties are not fully known. As a consequence, the choice between them is typically made on the basis of computational facility. This paper uses the Wald test since it requires only the unrestricted estimator.

Now let $\hat{\Theta}$ be the vector of parameter estimates obtained without restrictions. For testing a set of linear restrictions such as $\mathbf{R}\Theta = \mathbf{q}$, the Wald test for the null hypothesis $H_0 : \mathbf{c}(\Theta) - \mathbf{q} = \mathbf{R}\Theta - \mathbf{q} = \mathbf{0}$ is based on

$$W = \left[\mathbf{R}\hat{\Theta} - \mathbf{q}\right]'\left[\mathbf{R}\mathbf{Var}\left(\hat{\Theta}\right)\mathbf{R}'\right]^{-1}\left[\mathbf{R}\hat{\Theta} - \mathbf{q}\right], \tag{35}$$

where $\mathbf{C} = \left[\dfrac{\partial \mathbf{c}\left(\hat{\Theta}\right)}{\partial \hat{\Theta}'}\right] = \mathbf{R}$ and $\mathbf{Var}\left[\mathbf{c}\left(\hat{\Theta}\right) - \mathbf{q}\right] = \mathbf{R}\mathbf{Var}\left(\hat{\Theta}\right)\mathbf{R}'$.

Under the null hypothesis, in large sample, the Wald statistic W has a χ^2(L) distribution, where L is the number of restrictions.

III. Diagnostic Tests on the Implied Series of Stochastic Discount Factors

A successful estimation of the parameters that appear in the system (15) by GMM enables us to obtain various candidates for $M_{t,t+1}$. What kinds of properties should they have? First of all, they must be always positive, since both the time-discount rate and marginal utility of consumption are positive.

[15] For more details, see, for example, Greene (1997).

(i) Hansen and Jagannathan's (1991) Volatility Bound Test

The second property is related to a so-called lower volatility bound. Hansen and Jagannathan (1991) proposed a set of restrictions in terms of a volatility bound derived from Euler equations (2) and (3). If the stochastic discount factor does not generate enough volatility, then it will lie outside Hansen and Jagannathan's volatility bound, which means that the asset pricing model is considered to be inconsistent with the asset market data. The most important merit of this test is that it is constructed purely from observable data so that it makes no reference to a particular model.

Now, let me briefly review the basic framework. Consider the least squares projection of the stochastic discount factor M [16] onto the space spanned by a vector of asset returns $\mathbf{R}$ and the constant as

$$M = \tilde{\mathbf{R}}'\theta_0 + \mu \,, \tag{36}$$

where $\tilde{\mathbf{R}}' = (1 \quad \mathbf{R}')$ and $E[\tilde{\mathbf{R}}'\mu] = \mathbf{0}$.

This implies that

$$\Theta_0 = \{E[\tilde{\mathbf{R}}\tilde{\mathbf{R}}']\}^{-1} E[\tilde{\mathbf{R}}M] \,. \tag{37}$$

If the second-moment matrix of the vector of asset returns $E[\tilde{\mathbf{R}}\tilde{\mathbf{R}}']$ is denoted $\mathbf{M_R}$, then Euler equations (2) and (3) imply that

$$\Theta_0 = \mathbf{M}_R^{-1}\begin{pmatrix} E[M] \\ \mathbf{l} \end{pmatrix}, \tag{38}$$

where $\mathbf{l}$ is a vector of ones conformable with $\mathbf{R}$. Since by construction, μ is orthogonal to $\tilde{\mathbf{R}}$, the following inequality must hold:

$$\begin{aligned} Var(M) &\geq \Theta_\mathbf{0}' E\{(\tilde{\mathbf{R}} - E[\tilde{\mathbf{R}}])(\tilde{\mathbf{R}} - E[\tilde{\mathbf{R}}])'\}\Theta_\mathbf{0} \\ &= (E[M] \quad \mathbf{l}')\mathbf{M}_R^{-1} E\{(\tilde{\mathbf{R}} - E[\tilde{\mathbf{R}}])(\tilde{\mathbf{R}} - E[\tilde{\mathbf{R}}])'\}\mathbf{M}_R^{-1}\begin{pmatrix} E[M] \\ \mathbf{l} \end{pmatrix}, \\ &= (\mathbf{l} - E[M]E[\mathbf{R}])'\Sigma_R^{-1}(\mathbf{l} - E[M]E[\mathbf{R}]) \end{aligned} \tag{39}$$

where Σ_R is the variance-covariance matrix of $\mathbf{R}$.

Furthermore, this paper attempts to conduct a statistical inference based on the volatility bound test. According to Cecchetti, Lam, and Mark (1994), two sources of uncertainty emerge when one compares the mean-variance pairs from the volatility bound to the stochastic discount factor counterparts. First, the computation of the mean-standard deviation pair for each stochastic discount factor is influenced by the estimated sample moments of the investment process. Second, volatility bounds must be constructed from the asset return data.

Making use of the GMM framework, estimation of the following system yields a distance measure and its standard error:

$$E[M_t - \alpha_M] = 0, \tag{40}$$

$$E[\mathbf{R}_t - \Psi] = 0, \tag{41}$$

$$E\left[(M_t - \alpha_M)^2 - Var_M\right] = 0, \tag{42}$$

$$E[\mathbf{1} - \alpha_M \mathbf{R}_t - (\mathbf{R}_t - \Psi)(\mathbf{R}_t - \Psi)'\Gamma] = 0, \tag{43}$$

and

$$E[Var_M - (\mathbf{1} - \alpha_M \mathbf{R})'\Gamma - \Delta] = 0, \tag{44}$$

where α_M, Ψ, Γ, Var_M, and Δ are parameters to be jointly estimated and Δ captures the distance between the variance of the candidate stochastic discount factor and the minimal volatility bound. For the sake of computational facility, let me adopt the following two-step procedure: (i) the system consisting of equations (40) and (41) are estimated by GMM to obtain sample means of the stochastic discount factor and returns, and then (ii) given this information, the rest of the equations are jointly estimated also by GMM[17].

The first step can be summarized in generic form: $E[g(\mathbf{y}_t, \lambda)] = 0$, where $\lambda = (\alpha_M, \psi')$ is the combined vector of coefficients and $\mathbf{y}_t$ represents data on returns and

[16] In this section, both M and M_t refer to $M_{t,t+1}$.

the stochastic discount factor. The GMM estimator of λ minimizes the quadratic form: $J_T^f(\omega) = \mathbf{g}_T^f(\lambda)' \mathbf{W}_T^f \mathbf{g}_T^f(\lambda)$, where $\mathbf{g}_T^f(\omega) = (1/T)\sum_{t=1}^T f(\mathbf{y}_t, \lambda)$ and $\mathbf{W}_T^f$ is some positive definite symmetric matrix. Similarly, the second step can be written as $E[h(\mathbf{y}_t, \xi)] = 0$, where $\xi = (Var_M, \Theta', \Delta)$. The GMM estimator of ξ can be obtained by minimizing $J_T^s(\xi) = \mathbf{g}_T^s(\xi)' \mathbf{W}_T^s \mathbf{g}_T^s(\xi)$, where $\mathbf{g}_T^s(\xi) = (1/T)\sum_{t=1}^T h(\mathbf{y}_t, \xi)$.

The estimator of the asymptotic covariance matrix of the vector $\sqrt{T}\left(\hat{\xi} - \xi_0\right)$ is given by the method due to Newey and West (1987). n=12 is used to estimate it as before. Under regularity conditions and under the null hypothesis $H_0 : \Delta = 0$, the Wald statistic satisfies the following property:

$$Z = \sqrt{T}\frac{\hat{\Delta}}{\hat{\sigma}_\Delta} \xrightarrow{d} N(0,1). \tag{45}$$

(ii) Mispricing Test of the Stochastic Discount Factor[18]

Lastly, the level of the stochastic discount factor should be consistent with the level of both the risk-free interest rate and other asset returns. Using the Law of Iterated Expectations, one can replace the conditional expectation in Euler equations (2) and (3) with an unconditional expectation such that

$$E\left[M_{t,t+1}R_{t,t+1}^f\right] = 1 \text{ and } E\left[M_{t,t+1}R_{t,t+1}^i\right] = 1 \qquad \text{for } i=1,...n \text{ th risky asset.} \tag{46}$$

These restrictions can be tested by estimating the following equation:

$$E\left[M_{t,t+1}\left(R_{t,t+1}^f + \phi^f\right)\right] = 1 \text{ and } E\left[M_{t,t+1}\left(R_{t,t+1}^i - R_{t,t+1}^f + \phi^i\right)\right] = 0 \tag{47}$$

where the new parameters φ s and their standard errors can be estimated by GMM. Again, Newey and West's (1987) method is used for correcting the bias in covariance matrix of parameters. If φ^i is found to be significantly negative, then it means that the

[17] This treatment implicitly assumes that the sample means of asset returns and the stochastic discount rate coincide with population means.

representative agent can gain at the margin by borrowing at the risk-free interest rate and investing in stocks. This is an equity premium puzzle. Similarly, if φ^f is found to be significantly positive, then it implies that the representative agent can gain marginally by transferring consumption from the future to the present. This is called a risk-free rate puzzle.

IV. The Data

(i) Data Description

A. Asset Returns

For the stock returns, I use the NIKKO Stock Performance Index (NIKKO SPI)[19] publicized by Nikko Securities Inc. Ltd. The most important reason for this choice is that it includes the dividend as well as the capital gain. Also, it is adjusted for the cross-share-holdings among publicly traded companies, which results in inflated market capitalization by double counting. The NIKKO SPI consists of 28 industry portfolios. As for the market return $R_{t,t+1}^{MKT}$, I use the weighted average return of 28 industry portfolios in excess of the risk-free interest rate (the collateralized overnight call rate). Table 1 describes industry portfolios.

In estimating the GMM system (15), one does not have to convert nominal returns into real terms since all the stock returns are expressed in excess of the risk-free interest rate. Other diagnostic tests, however, require that this be done. In this paper, I follow the Fama and Gibbons (1982, 1984) methodology to construct the expected inflation series[20]. They start with the Fisher (1930) equation:

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[18] See Ferson and Constantinides (1991), Bakshi and Naka (1997), and Kocherlakota (1996) for similar tests.

[19] This index covers all the stocks listed on the Tokyo, Osaka, and Nagoya Stock Exchanges as well as on the over-the-counter market. Hence coverage is more comprehensive than previous studies such as that conducted by Choi, Hiraki, and Takezawa (1998), who examine all the stock returns listed on the first section of the Tokyo Stock Exchange.

[20] I also used *ex post* inflation to get real returns, which produces almost identical results.

$$E[\pi_{t,t+1} \mid \Omega_t] = r_{t-1,t} - E[R_{t,t+1} \mid \Omega_t], \tag{48}$$

where $\pi_{t,t+1}$ is future consumer price index inflation, $r_{t-1,t}$ is the nominal interest rate that is observed at the start of time *t*, and $R_{t,t+1}$ is the future real interest rate. Now let me define the *ex post* real interest rate as $R^{ex}_{t,t+1} \equiv r_{t-1,t} - \pi_{t,t+1}$. It thus follows that $R^{ex}_{t,t+1} = E[R_{t,t+1} \mid \Omega_t] + \varepsilon_{t+1}$. Then the difference between the real interest rates for time *t*+1 and *t* is

$$R^{ex}_{t,t+1} - R^{ex}_{t-1,t} = \Delta E[R_{t,t+1} \mid \Omega_t] + \varepsilon_{t+1} - \varepsilon_t, \tag{49}$$

where $\Delta E[R_{t,t+1} \mid \Omega_t]$ is the change in the expected real return from time *t*+1 to *t*, and ε_{t+1} is the unexpected component of the real interest rate for time *t*+1. Here, it should be noted that if $E[R_{t,t+1} \mid \Omega_t]$ follows a random walk, $\Delta E[R_{t,t+1} \mid \Omega_t]$ and ε_{t+1} are both white noise. Now, according to Box and Jenkins (1976), the difference between real interest rates for time *t*+1 and *t* can then be represented as a first-order moving average (MA[1]) process:

$$R^{ex}_{t,t+1} - R^{ex}_{t-1,t} = u_{t+1} - \lambda u_t, \tag{50}$$

where the moving average parameter λ is close to 1.0 when the variance of ε_{t+1} is large enough relative to the variance of $\Delta E[R_{t,t+1} \mid \Omega_t]$, and is close to 0.0 vice versa.

Substituting equation (50) into equation (49) gives the following formula of the expected inflation series:

$$E[\pi_{t,t+1} \mid \Omega_t] = r_{t-1,t} - R^{ex}_{t-1,t} - \lambda u_t. \tag{51}$$

To construct this series, I take the value of λ=0.5. Now I start with u_1=0. Then I construct u_t successively by

$$R^{ex}_{1,2} - R^{ex}_{0,1} = u_2, \quad R^{ex}_{2,3} - R^{ex}_{1,2} = u_3 - \lambda u_2, \tag{52}$$

and so on. The expected real return is then given by

$$E[R_{t,t+1} \mid \Omega_t] = E[R_{t-1,t} \mid \Omega_{t-1}] + (1-0.5)u_t. \tag{53}$$

B. Foreign Exchange Rate and Interest Rate

Concerning the foreign exchange rate innovation $R_{t,t+1}^{EX}$, I use the rate of change in a trade-weighted effective real exchange rate measured as the foreign currency price computed by JP Morgan. A positive value of $R_{t,t+1}^{EX}$ indicates an appreciation of the yen. This specification is appropriate only if the change in the exchange rate is essentially unpredictable[21]. Another possibility would be to take the forward premium on the foreign exchange rate as the expected rate of change in the exchange rate. A growing number of empirical studies show, however, that the forward rate is not an unbiased estimator of the future spot rate[22], and does not outperform the current spot rate in terms of prediction[23].

As for the interest rate innovation $R_{t,t+1}^{INT}$, I use the first difference in the interest rate of the long-term (10-year) government bond, whose degree of liquidity is thought to be the highest in the Japanese bond market.

C. Instrumental Variables

As mentioned in the last section, financial data such as UPR (default risk premium) and UTS (term structure) can be obtained without delay so that one can include them as of time *t* in the information set. In contrast, there is some delay in the case of IP (the growth rate in the industrial production) and UI (unexpected inflation)[24]

[21] It turns out that the process of the rate of change in the effective exchange rate of the yen is not a white noise, which suggests that it should have a predictable component. Despite this fact, however, I employ this form mainly for ease of comparison with preceding research.
[22] For this point, see Fama (1984).
[23] In fact, forecasting the nominal exchange rate is a difficult task. Studies such as Meese and Rogoff (1983, 1988) and Campbell and Clarida (1987) are typical of the empirical literature that seeks to explain and forecast the monthly and/or quarterly exchange rate using traditional macroeconomic fundamentals. The dispiriting conclusion is that relatively little explanatory power is found, and the models show little forecasting ability compared to simple alternatives such as a random walk model.
[24] UI is constructed by subtracting expected inflation derived by Fama and Gibbon's (1982, 1984) method from actual CPI inflation.

because they are processed data. Thus, I include the data of both industrial production and unexpected inflation[25] at time *t*-2 in the information set.

The sample period runs from January 1980 to December 1998, which means that I can exclude the effects of the first [1973] and second [1979] oil shocks. Table 2 describes the definition and source of each variable.

D. Coping with Seasonality and Trading-Day Effects

In this paper, every time-series data is adjusted for seasonality and trading-day effects by the program named "Decomp," which was originally developed by Kitagawa and Gersch (1984) and was refined by Kitagawa (1995) and others. "Decomp" can now be accessed on the Education Ministry's Institute of Statistical Mathematics web site[26]. By this method one can decompose any time-series data into not only trend, seasonal and autoregressive (AR) components, but one also into the component of trading-day effects, which cannot be estimated by other methods such as X11 despite the fact that it is sometimes an important component, especially in the case of stock returns[27].

(ii) Properties of the Data

A. Summary Statistics

Table 3(i) describes summary statistics of some of the data, which are adjusted for seasonality and trading-day effect. All asset returns are in real terms. As can easily be expected, market return exhibits the highest volatility. Also, the effective exchange rate fluctuates widely, although its standard deviation is much smaller than that of the market return.

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[25] Unexpected inflation is estimated by the method of Fama and Gibbons (1982, 1984).
[26] One can access "DECOMP" at "http://ssnt.ism.ac.jp/inets/inets_eng.html."
[27] A number of studies have uncovered evidence that refutes the assumption that the expected daily returns on stocks are the same for all days of the week. For example, two early studies (French [1980] and Gibbons and Hess [1981]) found that the return on Monday was quite different from those on other days.

The 6th and 7th columns in Table 3(i) demonstrate the excess skewness and kurtosis. The estimation result shows that the excess skewness for the monthly market return is negative, and the excess kurtosis is positive, which indicates that it has more mass in the tail areas than would be predicted by a normal distribution. This result shows that the Japanese market return has similar characteristics to those of its U.S. counterpart[28].

Additionally, to investigate the autocorrelation pattern of the data set, Table 3(i) reports Ljung and Box's (1978) *Q*-statistic. This statistic is known to be distributed χ^2 with degrees of freedom under the null hypothesis of no auto-correlation to the order *L*. The estimation result suggests that, with the exception of the market return, there is a significant auto-correlation pattern, which implies it is only in the Japanese market return that there is no predictable component as far as this period is concerned.

B. Correlation Matrix

Table 3(ii) reports coefficients of correlation between these variables. First, it should be noted that correlation between any two of the potential risk factors is relatively high and so there is a concern that the estimated pricing coefficients in the case of two- and three-factor models might be biased. To alleviate this concern, I calculate the components of the foreign exchange rate and the long-term interest rate that are orthogonal to the market return using the following method:

[Two-Factor Model][29] $\hat{R}^{k}_{t,t+1} = R^{k}_{t,t+1} - \left(\hat{a}_0 + \hat{a}_1 R^{MKT}_{t,t+1}\right)$ *k*=EX or INT (54)

[Three-Factor Model] $\hat{R}^{EX}_{t,t+1} = R^{EX}_{t,t+1} - \left(\hat{b}_0 + \hat{b}_1 \hat{R}^{MKT}_{t,t+1}\right)$ and (55)

$$\hat{R}^{INT}_{t,t+1} = R^{INT}_{t,t+1} - \left(\hat{c}_0 + \hat{c}_1 \hat{R}^{MKT}_{t,t+1} + \hat{c}_2 R^{EX}_{t,t+1}\right), \tag{56}$$

[28] For detailed analysis of the U.S. asset returns, see Campbell, Lo, and MacKinlay (1997).
[29] In the case in which the foreign exchange rate and the long-term interest rate are used as potential risk factors, I estimate the component of the long-term interest rate to be orthogonal to the foreign exchange rate, leaving the foreign exchange rate as it is. But, this order of orthogonalization did not alter the final estimation results.

where $\hat{R}^{k}_{t,t+1}$ represents the residual derived from the OLS estimation.

Second, the correlation between potential risk factors and instrumental variables is not high, but it is at least similar to or higher than others, including that obtained by Choi, Hiraki, and Takezawa (1998).

V. Empirical Results

(i) Overall Estimation Results

Since the GMM estimation of the conditional model reflects the intertemporal changes in the information set, I have estimated the model only for the entire sample period (March 1980-December 1998)[30] rather than by sub-periods. The estimation results are summarized in Table 4, and the details are described in Table 5 (one-factor model), Table 6 (two-factor model), and Table 7 (three-factor model).

First, let me briefly comment on the overall result in Table 4. The test result based on the GMM estimation suggests that for all the specifications, (i) the null hypothesis of no-overriding restrictions cannot be significantly rejected (*J*-test), (ii) the pricing coefficients are significantly estimated, and (iii) the time-varying pricing coefficients are jointly found to be significantly different from zero (Wald test). In this regard, one cannot tell whether or not currency risk is really priced in the Japanese stock market since one does not have any criteria by which one can judge which specification is the best. Only one thing for sure at this stage, however, is that time-variance of any pricing coefficients is not significantly rejected regardless of which potential risk factors are used. Many preceding studies including Dumas and Solnik (1995) and Choi, Hiraki, and Takezawa (1998) stopped here, concluding that currency risk is priced without further examination.

[30] My original data set covers the period starting in January 1980 mainly due to the availability of the stock return data. Since IP and UI should be lagged twice, the estimation period starts in March 1980.

Next, according to the result of the diagnostic tests on the stochastic discount factors implied by each specification, many specifications are found to have failed to satisfy the restrictions they should satisfy. For example, only three specifications satisfy a non-negativity restriction for the sample period, and only one specification satisfies Hansen and Jagannathan's volatility bound test. Also, the mispricing test shows that six specifications fail to explain the movement of the actual asset returns.

Summing up, a one-factor model with the market return as a sole risk factor, in which Z2 is used as the information set, performs the best of all the specifications and so best describes the Japanese stock market as far as this period is concerned. Below, let me comment on the result in more detail.

(ii) Detailed Estimation Results

A. Tests Based on the GMM Estimation

Tables 5, 6, and 7 report more detailed estimation results for each model. First, as evidenced by the *J*- test for overidentifying restrictions with a *p*-value of 0.999, no specification is rejected by the data.

Second, the result shows the pattern of potential relationship between the price of each risk factor and the instrumental variables. Typically, an increase in industrial production and default risk premium significantly affect the price of market risk positively. Also, an increase in the default risk premium significantly affects the price of currency risk positively, while an increase in industrial production, unexpected inflation, and the term structure of interest rates significantly affect it negatively. Moreover, an increase in industrial production, unexpected inflation, and the term structure positively affects the price of long-term interest rate, while an increase in the default risk premium negatively affects it.

Lastly, the Wald statistics reject the null hypothesis for each potential risk factor significantly at the 1% level for every specification, which suggests that the estimated pricing coefficients should be time-varying conditional on each information set.

B. Results of Diagnostic Tests on the Implied Stochastic Discount Factor

First, Figures 1, 2, and 3 show the time-series movement of the stochastic discount factors derived by various specifications. They reveal that only a few specifications satisfy the most fundamental restriction of non-negativity. In particular, it should be noted that all the specifications including currency risk as one of the potential risk factors fail to satisfy this restriction.

Second, the result of the volatility bound test is even more striking. Figure 4 plots the pairs of the sample mean and the variance of the stochastic discount factor in addition to the lower volatility bound derived from the portfolio consisting of the market return and the risk-free interest rate. The result shows that only the one case in which the market return is the sole risk factor, with the default risk premium and the term structure as instrumental variables, satisfies the lower volatility bound.

Lastly, the result of mispricing test reports that except for the case of one-factor model with the market return as a sole risk factor, the use of the information set Z1, which consists of industrial production and unexpected inflation as well as the default risk premium and the term structure, leads to mispricing of the risk-free interest rate. Typically, the use of the information set Z1 tends to yield a low mean value of the stochastic discount factor so that the risk-free interest rate should be much higher than the actual value in order for the Euler equation for the risk-free interest rate to hold. This result suggests that a risk-free rate puzzle is much more formidable than an equity premium puzzle in Japan as far as this sample period is concerned.

VI. Concluding Remarks

This paper has attempted to reexamine the *ex ante* pricing of currency risk in the Japanese stock market within a framework of the conditional APT, which has time-varying pricing coefficients of potential risk factors including the market return and the long-term interest rate as well as the foreign exchange rate. In addition to the ordinary GMM estimation of pricing coefficients, special emphasis is placed on the validity of the implied series of stochastic discount factors, because this point of view is often ignored in the APT or multiple-factor asset pricing models.

According to the empirical results, although a fairly good performance is recorded in terms of the GMM estimation in the case in which currency risk is included as a potential risk factor, the stochastic discount factor derived from it almost always violates the required restrictions, that is, a non-negativity restriction and the volatility bound restriction. It turns out that the model with market return as the sole risk factor performs the best of all the specifications, especially in terms of the properties of its stochastic discount factor. So one should avoid hasty decisions regarding whether or not currency risk is priced *ex ante* in the Japanese stock market without thoroughly investigating the restrictions that potential stochastic discount factors should satisfy.

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Table 1: Industry Portfolios

Portfolio Number	Industry Name	Capitalization Weight (%) Jan 1980	Dec 1998
R1	Fishery, Agriculture, and Forestry	0.174	0.108
R2	Mining	0.614	0.089
R3	Construction	4.310	2.513
R4	Foods	3.596	3.409
R5	Textiles and Apparels	2.173	1.311
R6	Pulp and Paper	0.860	0.559
R7	Chemicals	7.463	9.346
R8	Oil and Coal Products	3.067	0.592
R9	Rubber Products	0.652	0.970
R10	Glass, Ceramics Products	1.793	1.134
R11	Iron and Steel	4.492	1.223
R12	Nonferrous Metals	1.859	0.998
R13	Metal Products	0.626	0.704
R14	Machinery	4.488	3.754
R15	Electric Appliances	10.777	13.854
R16	Transportation Equipment	7.065	6.390
R17	Precision Instruments	1.243	0.891
R18	Other Products	1.391	2.428
R19	Commerce	8.615	9.114
R20	Banking and Insurance	20.149	17.512
R21	Real Estate	1.219	1.036
R22	Land Transportation	3.424	4.829
R23	Marine Transportation	1.231	0.230
R24	Air Transportation	0.649	0.410
R25	Warehousing and Harbor Transportation	0.319	0.261
R26	Communication	0.330	7.471
R27	Electric Power and Gas	6.539	5.378
R28	Services	0.885	3.485
R^{MKT}		100.000	100.000

Note: Industry portfolios used here are taken from the NIKKO Stock Performance Index issued by Nikko Securities Co. Ltd. It covers all the stocks listed on Tokyo, Osaka, and Nagoya Stock Exchanges, as well as on the over-the-counter market. It is adjusted for cross-share-holding

Table 2: Definition of Economic Variables

Symbol	Definition	Source
Economic Risk Factors		
R^{MKT}	The value-weighted stock market return (NIKKO SPI) in excess of the risk-free return	Nikko Securities Co. Ltd.
R^{EX}	The rate of change in the effective (bilateral-trade-weighted) real exchange rate of the yen	JP Morgan
R^{INT}	The first difference in the interest rate on the 10-year Japanese government bond	Economic Statistics, Monthly, Bank of Japan
Instrumental Variables		
IP	The rate of growth in industrial production	IFS, IMF
UI	Unexpected inflation constructed by subtracting expected inflation derived by Fama and Gibbons' (1982, 84) method from the actual inflation rate	Economic Statistics, Monthly, Bank of Japan
UPR	Default risk premium defined as the difference between returns on the corporate bond and the 10-year government bond	Economic Statistics, Monthly, Bank of Japan
UTS	Term structure defined as the difference between the 10-year government bond return and the risk-free return (call rate)	Economic Statistics, Monthly, Bank of Japan

Note: R^{EX} is computed from JP Morgan's narrow effective real exchange rate index. This index measures the yen's strength against a basket consisting of currencies of Canada, Germany, France, Italy, U.K., Australia, Belgium, Denmark, Finland, Netherlands, Norway, Spain, Sweden, Switzerland, Greece, Austria, Portugal, and USA. It is weighted to reflect the global pattern of bilateral trade in manufactures in 1995 based to the average of 1995=100

Table 3: Properties of the Data Set
(i) Summary Statistics (January 1980-December 1998)

	Mean	S. D	Min	Max	Skewness	Kurtosis	Q(1)	Q(6)	Q(12)
R^{MKT}	0.00229	0.05261	-0.21030	0.18880	-0.19546	1.62292	0.79 [0.375]	5.19 [0.520]	9.90 [0.625]
R^{EX}	0.00091	0.02092	-0.05700	0.06215	0.51000	0.47948	25.9 [0.000]	30.6 [0.000]	39.8 [0.000]
R^{INT}	-0.00002	0.00028	-0.00108	0.00097	0.18696	1.69310	2.05 [0.152]	18.5 [0.005]	24.0 [0.020]
IP	0.00438	0.00100	-0.02302	0.03266	0.01298	0.03422	9.48 [0.000]	54.8 [0.000]	65.1 [0.000]
UI	0.00001	0.00193	-0.00593	0.00512	-0.18795	0.58382	25.8 [0.000]	39.6 [0.000]	50.4 [0.000]
UPR	0.00032	0.00031	-0.00058	0.00126	0.08600	0.43519	153 [0.000]	624 [0.000]	968 [0.000]
UTS	0.00072	0.00105	-0.00337	0.00263	-1.03244	1.45872	203 [0.000]	858 [0.000]	1170 [0.000]

(ii) Correlation Matrix between Economic Factors (March 1980-December 1998)

	R^{MKT}	R^{EX}	R^{INT}	IP (-2)	UI (-2)	UPR	UTS
Economic Risk Factors							
R^{MKT}	1.000						
R^{EX}	0.104	1.000					
R^{INT}	-0.117	-0.161	1.000				
Instrumental Variables							
IP (-2)	0.090	-0.026	0.040	1.000			
UI (-2)	-0.112	0.093	0.061	0.002	1.000		
UPR	0.085	0.126	-0.232	-0.132	-0.019	1.000	
UTS	-0.035	-0.185	0.139	0.106	-0.082	0.029	1.000

Notes: 1. Economic variables are defined as follows: R^{MKT}: the real return on the market portfolio in excess of the risk-free interest rate (collateralized overnight call rate), R^{EX} : the rate of change in effective real exchange rate of the yen. R^{INT} : the first difference in the interest rate on the Japanese 10-year government bond , IP: the rate of growth in industrial production. UI: unexpected inflation. UPR: default risk premium defined as the difference between the government bond return and the corporate bond return. UTS: term structure defined as the difference between the 10-year government bond return and collateralized call rate. All variables are adjusted for seasonality and trading-day effects by the web-based program "DECOMP".

2. Q(L) is Ljung and Box's (1978) Q-statistic at lag length of *L*. The Q(L) static is distributed χ^2 (L) under the null hypothesis of no serial correlation to the order *L*. The *p*-values are reported in brackets.

Table 4: Summary of the Estimation Results

Specification		Tests Based on the GMM Estimation			Diagnostic Tests on the Implied Series of Stochastic Discount Factors		
		J-test	Parameter Estimates	Wald Test	Non-Negativity Test	H-J Volatility Bound Test	Mispricing Test
One-Factor Model							
R^{MKT}	Z1	O	O	O	O	X	O
	Z2	O	O	O	O	O	O
R^{EX}	Z1	O	O	O	X	X	X
	Z2	O	O	O	X	X	O
R^{INT}	Z1	O	O	O	X	X	X
	Z2	O	O	O	X	X	O
Two-Factor Model							
R^{MKT} & R^{EX}	Z1	O	O	O	X	X	X
	Z2	O	O	O	X	X	O
R^{MKT} & R^{INT}	Z1	O	O	O	O	X	X
	Z2	O	O	O	X	X	O
R^{EX} & R^{INT}	Z1	O	O	O	X	X	X
	Z2	O	O	O	X	X	O
Three-Factor Model							
R^{MKT} ,R^{EX}, & R^{INT}	Z1	O	O	O	X	X	X
	Z2	O	O	O	X	X	O

Notes: In the following cases, I put O in the corresponding columns, otherwise, put X.

1. For the *J*-test, the null hypothesis of no-overidentifying restrictions cannot be rejected at the 5% significance level (right-tail *p*-value)
2. For the parameter estimates, at least one of the pricing (time-varying) coefficients are significantly (at the 5% level) different from zero.
3. For the Wald test, time-varying pricing coefficients are jointly different from zero at the 5% significance level.
4. For the non-negativity test, the stochastic discount factor is always positive throughout the sample period.
5. For the H-J volatility bound test, the distance measure takes a positive value or is not significantly (at the 5% level) different from zero in the case in which it takes a negative value.
6. For the mispricing test, the mispricing coefficients are not significantly (at the 5% level) different from zero.

Table 5: Estimation of the Conditional One-Factor APT (Mar 1980-Dec 1998)

(i) Market Return

[Basic Estimation Results by GMM]

(Z1) $\gamma_t^0 = -\left(\Phi^0_{Constant} + \Phi^0_{IP} IP_{t-2} + \Phi^0_{UI} UI_{t-2} + \Phi^0_{UPR} UPR_t + \Phi^0_{UTS} UTS_t\right)$

$\gamma_t^k = \Phi^k_{Constant} + \Phi^k_{IP} IP_{t-2} + \Phi^k_{UI} UI_{t-2} + \Phi^k_{UPR} UPR_t + \Phi^k_{UTS} UTS_t$ for k=MKT

(Z2) $\gamma_t^0 = -\left(\Phi^0_{Constant} + \Phi^0_{UPR} UPR_t + \Phi^0_{UTS} UTS_t\right)$

$\gamma_t^k = \Phi^k_{Constant} + \Phi^k_{UPR} UPR_t + \Phi^k_{UTS} UTS_t$ for k=MKT

	Z1		Z2	
	γ^0	γ^{MKT}	γ^0	γ^{MKT}
$\Phi_{Constant}$	0.404E-02	-2.244	-0.588E-02	-1.153
	(0.784)	(-4.532)***	(-2.528)**	(-1.455)
Φ^j_{IP}	2.266	218.26		
	(5.140)***	(6.881)***		
Φ^j_{UI}	-8.084	-1463.24		
	(-3.159)***	(-14.33)***		
Φ^j_{UPR}	66.710	6329.78	71.095	6853.46
	(4.026)***	(6.652)***	(3.087)***	(4.323)***
Φ^j_{UTS}	-17.207	-551.50	-7.132	-244.30
	(-5.578)***	(-1.835)***	(-2.315)**	(-0.541)
J-test (χ^2)	18.195		17.885	
p-value	(0.999)		(0.999)	

Notes: 1. γ^0 is the time-varying constant, and γ^{MKT} is the price of market risk in the GMM system (15).
2. The *t*-values are reported in parentheses. (*: significant at the 10% level. **: significant at the 5% level. ***: significant at the 1% level.) The *J*-test for overidentifying restrictions is distributed χ^2.

[Hypothesis Testing (Wald Tests) on the Estimated Pricing Coefficients]

Null Hypothesis: (Z1) $\Phi^k_{Constant}=\Phi^k_{IP}=\Phi^k_{UI}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0 or MKT
(Z2) $\Phi^k_{Constant}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0 or MKT

	Z1		Z2	
	k=0	k=MKT	k=0	k=MKT
χ^2	39.643	335.965	11.751	29.250
p-value	0.000	0.000	0.008	0.000

Null Hypothesis: (Z1) $\Phi^k_{IP}=\Phi^k_{UI}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0 or MKT
(Z2) $\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0 or MKT

	Z1		Z2	
	k=0	k=MKT	k=0	k=MKT
χ^2	36.258	308.506	9.569	18.923
p-value	0.000	0.000	0.008	0.000

Null Hypothesis: (Z1) $\Phi^k_{IP}=\Phi^k_{UI}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for all k
(Z2) $\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for all k

	Z1	Z2
	k=0 & MKT	k=0 & MKT
χ^2	474.627	19.308
p-value	0.000	0.001

[Volatility Bound Test]

$$\hat{\Delta} = Var(\hat{M}) - (\mathbf{1} - E[\hat{M}]E[\mathbf{R}])'\Sigma_R^{-1}(\mathbf{1} - E[\hat{M}]E[\mathbf{R}])$$

$$Z = \sqrt{T}\,\frac{\hat{\Delta}}{\hat{\sigma}_\Delta} \xrightarrow{d} N(0,1)$$

	Z1	Z2
E[M]	0.983	0.998
Var[M]	0.038	0.013
Δ (distance measure)	-7.738	0.902E-02
Z (Wald Statistic)	-7.432	0.824
p-value	0.000	0.795

[Mispricing Test]

$$E\left[M_{t,t+1}\left(R^f_{t,t+1} + \phi^f\right)\right] = 1 \,,$$

and $E\left[M_{t,t+1}\left(R^i_{t,t+1} - R^f_{t,t+1} + \phi^i\right)\right] = 0$ for i=1,...n th risky asset

	Z1	Z2
ϕ^{Rf}	0.015 (1.213)	-0.259E-03 (-0.027)
ϕ^{R1}	0.174E-02 (0.372)	0.278E-02 (0.595)
ϕ^{R2}	0.410E-02 (0.705)	0.642E-02 (1.102)
ϕ^{R3}	0.111E-02 (0.194)	0.251E-02 (0.441)
ϕ^{R4}	-0.967E-03 (-0.234)	-0.126E-03 (-0.032)
ϕ^{R5}	0.328E-04 (0.007)	0.181E-02 (0.408)
ϕ^{R6}	0.881E-04 (0.019)	0.177E-02 (0.362)
ϕ^{R7}	-0.198E-02 (-0.515)	-0.590E-03 (-0.164)
ϕ^{R8}	0.416E-02 (0.915)	0.547E-02 (1.139)
ϕ^{R9}	-0.323E-02 (-0.707)	-0.239E-02 (-0.569)
ϕ^{R10}	-0.141E-03 (-0.031)	0.144E-02 (0.314)
ϕ^{R11}	0.155E-02 (0.245)	0.314E-02 (0.472)
ϕ^{R12}	0.862E-03 (0.180)	0.209E-02 (0.434)
ϕ^{R13}	-0.257E-03 (-0.050)	0.891E-03 (0.172)
ϕ^{R14}	0.327E-03 (0.068)	0.185E-02 (0.380)
ϕ^{R15}	-0.308E-02 (-0.629)	-0.183E-02 (-0.380)
ϕ^{R16}	-0.164E-02 (-0.352)	-0.664E-03 (-0.150)
ϕ^{R17}	-0.332E-02 (-0.718)	-0.203E-02 (-0.449)
ϕ^{R18}	-0.227E-02 (-0.523)	-0.124E-02 (-0.296)
ϕ^{R19}	0.540E-02 (0.012)	0.135E-02 (0.308)
ϕ^{R20}	0.201E-02 (0.003)	0.110E-02 (0.182)
ϕ^{R21}	0.421E-02 (0.067)	0.265E-02 (0.425)
ϕ^{R22}	-0.352E-02 (-0.662)	-0.188E-02 (-0.351)
ϕ^{R23}	0.637E-02 (1.132)	0.699E-02 (1.262)
ϕ^{R24}	0.159E-02 (0.263)	0.143E-02 (0.233)
ϕ^{R25}	-0.110E-03 (-0.205)	0.824E-03 (0.158)
ϕ^{R26}	-0.402E-02 (-0.505)	-0.323E-02 (-0.434)
ϕ^{R27}	-0.234E-02 (-0.440)	-0.297E-02 (-0.568)
ϕ^{R28}	-0.838E-03 (-0.168)	-0.374E-03 (-0.074)

Notes: 1. Estimation is based on the unconditional version of GMM. The system is exactly identified so that unconditional sample moments are used to estimate mispricing coefficients.

2. The *t*-values are reported in parentheses (*: significant at the 10% level. **: significant at the 5% level. ***: significant at the 1% level.), which are calculated based on standard errors that are corrected for the heteroscedasticity by White's (1980) method and the autocorrelation by Newey and West's (1987) method (a lag length of 12 months is used).

(ii) Foreign Exchange Rate

[Basic Estimation Results by GMM]

(Z1) $\gamma_t^0 = -\left(\Phi_{Constant}^0 + \Phi_{IP}^0 IP_{t-2} + \Phi_{UI}^0 UI_{t-2} + \Phi_{UPR}^0 UPR_t + \Phi_{UTS}^0 UTS_t\right)$

$\gamma_t^k = \Phi_{Constant}^k + \Phi_{IP}^k IP_{t-2} + \Phi_{UI}^k UI_{t-2} + \Phi_{UPR}^k UPR_t + \Phi_{UTS}^k UTS_t$ for k=EX

(Z2) $\gamma_t^0 = -\left(\Phi_{Constant}^0 + \Phi_{UPR}^0 UPR_t + \Phi_{UTS}^0 UTS_t\right)$

$\gamma_t^k = \Phi_{Constant}^k + \Phi_{UPR}^k UPR_t + \Phi_{UTS}^k UTS_t$ for k=EX

	Z1		Z2	
	γ^0	γ^{EX}	γ^0	γ^{EX}
$\Phi_{Constant}$	-0.130	-5.098	0.419E-02	-0.761
	(-15.79)***	(-4.010)***	(-0.291)	(-0.352)
Φ^j_{IP}	-1.346	-74.124		
	(-3.902)***	(-1.191)		
Φ^j_{UI}	15.960	-4090.00		
	(7.637)***	(-12.41)***		
Φ^j_{UPR}	44.842	18924.4	196.806	28504.7
	(1.965)**	(12.26)***	(5.778)***	(10.58)***
Φ^j_{UTS}	54.014	-2652.65	-52.435	-6265.65
	(8.248)***	(-4.018)***	(-4.502)***	(-7.024)***
J-test (χ^2)	18.202		17.901	
p-value	(0.999)		(0.999)	

Notes: 1. γ^0 is the time-varying constant, and γ^{MKT} is the price of market risk in the GMM system (15).
2. The *t*-values are reported in parentheses. (*: significant at the 10% level. **: significant at the 5% level. ***: significant at the 1% level.) The *J*-test for overidentifying restrictions is distributed χ^2.

[Hypothesis Testing (Wald Tests) on the Estimated Pricing Coefficients]

Null Hypothesis: (Z1) $\Phi^k_{Constant}=\Phi^k_{IP}=\Phi^k_{UI}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0 or EX
(Z2) $\Phi^k_{Constant}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0 or EX

	Z1		Z2	
	k=0	*k*=EX	*k*=0	*k*=EX
χ^2	628.528	756.766	40.633	243.598
p-value	0.000	0.000	0.000	0.000

Null Hypothesis: (Z1) $\Phi^k_{IP}=\Phi^k_{UI}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0 or EX
(Z2) $\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0 or EX

	Z1		Z2	
	k=0	*k*=EX	*k*=0	*k*=EX
χ^2	300.251	524.000	38.520	122.444
p-value	0.000	0.000	0.000	0.000

Null Hypothesis: (Z1) $\Phi^k_{IP}=\Phi^k_{UI}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for all k
(Z2) $\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for all k

	Z1	Z2
	k=0 & EX	*k*=0 & EX
χ^2	886.091	174.667
p-value	0.000	0.000

[Volatility Bound Test]

$$\hat{\Delta} = Var(\hat{M}) - (\mathbf{1} - E[\hat{M}]E[\mathbf{R}])'\Sigma_R^{-1}(\mathbf{1} - E[\hat{M}]E[\mathbf{R}])$$

$$Z = \sqrt{T}\,\frac{\hat{\Delta}}{\hat{\sigma}_\Delta} \xrightarrow{d} N(0,1)$$

	Z1	Z2
E[M]	0.907	0.976
Var[M]	0.053	0.069
Δ (distance measure)	-314.068	-18.384
Z (Wald Statistic)	-8.307	-7.852
p-value	0.000	0.000

[Mispricing Test]

$$E\left[M_{t,t+1}\left(R^f_{t,t+1} + \phi^f\right)\right] = 1 \text{ ,}$$

and $E\left[M_{t,t+1}\left(R^i_{t,t+1} - R^f_{t,t+1} + \phi^i\right)\right] = 0$ for i=1,...n th risky asset

	Z1	Z2
ϕ^{Rf}	0.100 (4.283)***	0.023 (0.953)
ϕ^{R1}	0.800E-03 (0.174)	0.155E-02 (0.330)
ϕ^{R2}	0.221E-02 (0.408)	0.332E-02 (0.565)
ϕ^{R3}	0.158E-02 (0.307)	0.121E-02 (0.209)
ϕ^{R4}	-0.507E-03 (-0.132)	-0.634E-03 (-0.160)
ϕ^{R5}	-0.591E-03 (0.137)	0.139E-03 (0.031)
ϕ^{R6}	-0.145E-02 (-0.298)	-0.543E-03 (-0.107)
ϕ^{R7}	-0.217E-02 (-0.602)	-0.189E-02 (-0.511)
ϕ^{R8}	0.268E-02 (0.579)	0.338E-02 (0.687)
ϕ^{R9}	-0.537E-02 (-1.241)	-0.531E-02 (-1.171)
ϕ^{R10}	-0.112E-03 (-0.025)	0.486E-04 (0.010)
ϕ^{R11}	-0.113E-02 (-0.017)	-0.212E-03 (-0.031)
ϕ^{R12}	-0.186E-02 (-0.384)	-0.352E-04 (-0.007)
ϕ^{R13}	-0.873E-03 (-0.174)	-0.423E-03 (-0.081)
ϕ^{R14}	-0.112E-03 (-0.241)	-0.719E-03 (-0.148)
ϕ^{R15}	-0.551E-02 (-1.184)	-0.418E-02 (-0.879)
ϕ^{R16}	-0.351E-02 (-0.780)	-0.664E-03 (-0.635)
ϕ^{R17}	-0.553E-02 (-1.294)	-0.388E-02 (-0.869)
ϕ^{R18}	-0.280E-02 (-0.692)	-0.283E-02 (-0.707)
ϕ^{R19}	-0.830E-02 (-0.191)	-0.101E-03 (-0.023)
ϕ^{R20}	0.630E-04 (0.011)	-0.794E-03 (-0.130)
ϕ^{R21}	0.224E-02 (0.378)	-0.447E-03 (-0.070)
ϕ^{R22}	-0.204E-02 (-0.407)	-0.283E-02 (-0.515)
ϕ^{R23}	0.327E-02 (0.575)	0.473E-02 (0.819)
ϕ^{R24}	-0.632E-03 (-0.103)	-0.249E-04 (-0.004)
ϕ^{R25}	-0.128E-03 (-0.250)	-0.146E-02 (-0.254)
ϕ^{R26}	-0.708E-02 (-0.939)	-0.495E-02 (-0.666)
ϕ^{R27}	-0.123E-02 (-0.267)	-0.309E-02 (-0.587)
ϕ^{R28}	-0.170E-02 (-0.353)	-0.166E-02 (-0.350)

Notes: 1. Estimation is based on the unconditional version of GMM. The system is exactly identified so that unconditional sample moments are used to estimate mispricing coefficients.

2. The *t*-values are reported in parentheses (*: significant at the 10% level. **: significant at the 5% level. ***: significant at the 1% level.), which are calculated based on standard errors that are corrected for the heteroscedasticity by White's (1980) method and the autocorrelation by Newey and West's (1987) method (a lag length of 12 months is used).

(iii) Long-Term Interest Rate

[Basic Estimation Results by GMM]

(Z1) $\gamma_t^0 = -\left(\Phi_{Constant}^0 + \Phi_{IP}^0 IP_{t-2} + \Phi_{UI}^0 UI_{t-2} + \Phi_{UPR}^0 UPR_t + \Phi_{UTS}^0 UTS_t\right)$

$\gamma_t^k = \Phi_{Constant}^k + \Phi_{IP}^k IP_{t-2} + \Phi_{UI}^k UI_{t-2} + \Phi_{UPR}^k UPR_t + \Phi_{UTS}^k UTS_t$ for k=INT

(Z2) $\gamma_t^0 = -\left(\Phi_{Constant}^0 + \Phi_{UPR}^0 UPR_t + \Phi_{UTS}^0 UTS_t\right)$

$\gamma_t^k = \Phi_{Constant}^k + \Phi_{UPR}^k UPR_t + \Phi_{UTS}^k UTS_t$ for k=INT

	Z1		Z2	
	γ^0	γ^{INT}	γ^0	γ^{INT}
$\Phi_{Constant}$	-0.020	294.656	0.027	777.367
	(-2.694)***	(3.232)***	(2.635)***	(6.635)***
Φ^j_{IP}	0.281	8226.29		
	(0.627)	(1.183)		
Φ^j_{UI}	13.624	186974		
	(4.746)***	(6.214)***		
Φ^j_{UPR}	-32.969	-0.143E+07	47.000	-0.243E+07
	(-1.427)	(-9.624)***	(1.402)	(-11.55)***
Φ^j_{UTS}	9.140	482705	-8.281	502724
	(1.184)	(12.18)***	(-1.067)	(10.80)***
J-test (χ^2)	18.189		17.845	
p-value	(0.999)		(0.999)	

Notes: 1. γ^0 is the time-varying constant, and γ^{MKT} is the price of market risk in the GMM system (15).
2. The t-values are reported in parentheses. (*: significant at the 10% level. **: significant at the 5% level. ***: significant at the 1% level.) The J-test for overidentifying restrictions is distributed χ^2.

[Hypothesis Testing (Wald Tests) on the Estimated Pricing Coefficients]

Null Hypothesis: (Z1) $\Phi^k_{Constant}=\Phi^k_{IP}=\Phi^k_{UI}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0 or INT
(Z2) $\Phi^k_{Constant}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0 or INT

	Z1		Z2	
	k=0	k=INT	k=0	k=INT
χ^2	49.295	309.557	23.441	225.975
p-value	0.000	0.000	0.000	0.000

Null Hypothesis: (Z1) $\Phi^k_{IP}=\Phi^k_{UI}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0 or INT
(Z2) $\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0 or INT

	Z1		Z2	
	k=0	k=INT	k=0	k=INT
χ^2	35.458	308.966	2.237	224.860
p-value	0.000	0.000	0.327	0.000

Null Hypothesis: (Z1) $\Phi^k_{IP}=\Phi^k_{UI}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for all k
(Z2) $\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for all k

	Z1	Z2
	k=0 & INT	k=0 & INT
χ^2	536.542	248.721
p-value	0.000	0.000

[Volatility Bound Test]

$$\hat{\Delta} = Var(\hat{M}) - (\mathbf{1} - E[\hat{M}]E[\mathbf{R}])'\Sigma_R^{-1}(\mathbf{1} - E[\hat{M}]E[\mathbf{R}])$$

$$Z = \sqrt{T}\,\frac{\hat{\Delta}}{\hat{\sigma}_{\Delta}} \xrightarrow{d} N(0,1)$$

	Z1	Z2
E[M]	0.927	0.976
Var[M]	0.048	0.069
Δ (distance measure)	-190.025	-18.384
Z (Wald Statistic)	-8.281	-7.852
p-value	0.000	0.000

[Mispricing Test]

$$E\left[M_{t,t+1}\left(R_{t,t+1}^{f} + \phi^{f}\right)\right] = 1 ,$$

and $$E\left[M_{t,t+1}\left(R_{t,t+1}^{i} - R_{t,t+1}^{f} + \phi^{i}\right)\right] = 0$$ for i=1,...n th risky asset

	Z1	Z2
ϕ^{Rf}	0.077 (3.766)***	0.022 (1.103)
ϕ^{R1}	0.143E-02 (0.307)	-0.156E-03 (-0.035)
ϕ^{R2}	0.209E-02 (0.349)	0.174E-02 (0.300)
ϕ^{R3}	0.119E-02 (0.219)	-0.929E-03 (-0.170)
ϕ^{R4}	-0.162E-02 (-0.400)	-0.304E-02 (-0.764)
ϕ^{R5}	-0.331E-03 (-0.074)	-0.165E-02 (-0.381)
ϕ^{R6}	-0.768E-03 (-0.161)	-0.145E-02 (-0.307)
ϕ^{R7}	-0.301E-02 (-0.820)	-0.459E-02 (-1.309)
ϕ^{R8}	0.318E-02 (0.697)	0.235E-02 (0.529)
ϕ^{R9}	-0.441E-02 (-1.084)	-0.574E-02 (-1.507)
ϕ^{R10}	-0.289E-03 (-0.062)	-0.206E-02 (-0.460)
ϕ^{R11}	0.495E-03 (0.078)	-0.111E-02 (-0.174)
ϕ^{R12}	-0.114E-02 (-0.245)	-0.187E-02 (-0.412)
ϕ^{R13}	-0.960E-03 (-0.019)	-0.152E-02 (-0.306)
ϕ^{R14}	0.478E-04 (0.010)	-0.105E-02 (-0.236)
ϕ^{R15}	-0.363E-02 (-0.793)	-0.445E-02 (-0.962)
ϕ^{R16}	-0.268E-02 (-0.604)	-0.344E-02 (-0.771)
ϕ^{R17}	-0.377E-02 (-0.844)	-0.436E-02 (-0.997)
ϕ^{R18}	-0.263E-02 (-0.658)	-0.415E-02 (-1.059)
ϕ^{R19}	-0.515E-03 (-0.118)	-0.187E-03 (-0.437)
ϕ^{R20}	-0.279E-02 (-0.462)	-0.452E-02 (-0.754)
ϕ^{R21}	-0.879E-03 (-0.156)	-0.330E-02 (-0.576)
ϕ^{R22}	-0.267E-02 (-0.525)	-0.436E-02 (-0.844)
ϕ^{R23}	0.610E-02 (1.075)	0.489E-02 (0.890)
ϕ^{R24}	0.206E-03 (0.035)	-0.114E-02 (-0.186)
ϕ^{R25}	-0.111E-02 (-0.224)	-0.232E-02 (-0.481)
ϕ^{R26}	-0.547E-02 (-0.707)	-0.597E-02 (-0.815)
ϕ^{R27}	-0.326E-02 (-0.685)	-0.545E-02 (-1.141)
ϕ^{R28}	-0.161E-02 (-0.330)	-0.335E-02 (-0.685)

Notes: 1. Estimation is based on the unconditional version of GMM. The system is exactly identified so that unconditional sample moments are used to estimate mispricing coefficients.

2. The *t*-values are reported in parentheses (*: significant at the 10% level. **: significant at the 5% level. ***: significant at the 1% level.), which are calculated based on standard errors that are corrected for the heteroscedasticity by White's (1980) method and the autocorrelation by Newey and West's (1987) method (a lag length of 12 months is used).

Table 6: Estimation of the Conditional Two-Factor APT (March 1980-December 1998)
(i) Market Return and Foreign Exchange Rate

[Basic Estimation Results by GMM]

$$\text{(Z1)}\quad \gamma_t^0 = -\left(\Phi^0_{Constant} + \Phi^0_{IP} IP_{t-2} + \Phi^0_{UI} UI_{t-2} + \Phi^0_{UPR} UPR_t + \Phi^0_{UTS} UTS_t\right)$$

$$\gamma_t^k = \Phi^k_{Constant} + \Phi^k_{IP} IP_{t-2} + \Phi^k_{UI} UI_{t-2} + \Phi^k_{UPR} UPR_t + \Phi^k_{UTS} UTS_t \quad \text{for } k=\text{MKT and EX}$$

$$\text{(Z2)}\quad \gamma_t^0 = -\left(\Phi^0_{Constant} + \Phi^0_{UPR} UPR_t + \Phi^0_{UTS} UTS_t\right)$$

$$\gamma_t^k = \Phi^k_{Constant} + \Phi^k_{UPR} UPR_t + \Phi^k_{UTS} UTS_t \quad \text{for } k=\text{MKT and EX}$$

	Z1			Z2		
	γ^0	γ^{MKT}	γ^{EX}	γ^0	γ^{MKT}	γ^{EX}
$\Phi_{Constant}$	-0.051	-2.649	0.594	0.839E-02	-1.311	-3.249
	(-4.290)***	(-5.144)***	(0.362)	(0.568)	(-1.849)*	(-1.402)
Φ^j_{IP}	1.044	252.962	-96.104			
	(1.754)*	(7.257)***	(-1.159)			
Φ^j_{UI}	5.063	-878.926	-3100.80			
	(1.639)	(-6.433)***	(-8.512)***			
Φ^j_{UPR}	145.383	4789.66	16358.1	174.298	7408.31	27377.9
	(5.562)***	(4.998)***	(7.638)***	(4.717)***	(6.138)***	(9.283)***
Φ^j_{UTS}	-18.730	-115.581	-3541.53	-36.639	-719.874	-6144.93
	(-2.201)**	(-0.384)	(-4.618)***	(-3.058)***	(-1.632)	(-6.665)***
J-test (χ^2)		18.190			17.897	
p-value		(0.999)			(0.999)	

Notes: 1. γ^0 is the time-varying constant, and γ^{MKT} is the price of market risk in the GMM system (15).
2. The *t*-values are reported in parentheses. (*: significant at the 10% level. **: significant at the 5% level. ***: significant at the 1% level.) The *J*-test for overidentifying restrictions is distributed χ^2.

[Hypothesis Testing (Wald Tests) on the Estimated Pricing Coefficients]

Null Hypothesis: (Z1) $\Phi^k_{Constant}=\Phi^k_{IP}=\Phi^k_{UI}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0, MKT, or EX
(Z2) $\Phi^k_{Constant}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0, MKT, or EX

	Z1			Z2		
	j=0	*j*=MKT	*j*=EX	*j*=0	*j*=MKT	*j*=EX
χ^2	77.843	136.089	300.284	34.644	54.024	172.133
p-value	0.000	0.000	0.000	0.000	0.000	0.000

Null Hypothesis: (Z1) $\Phi^k_{IP}=\Phi^k_{UI}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0, MKT, or EX
(Z2) $\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0, MKT, or EX

	Z1			Z2		
	j=0	*j*=MKT	*j*=EX	*j*=0	*j*=MKT	*j*=EX
χ^2	61.550	127.019	188.269	22.623	37.846	97.661
p-value	0.000	0.000	0.000	0.000	0.000	0.000

Null Hypothesis: (Z1) $\Phi^k_{IP}=\Phi^k_{UI}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for all k
(Z2) $\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for all k

	Z1	Z2
	k=0, MKT, & EX	k=0, MKT, & EX
χ^2	633.820	212.059
p-value	0.000	0.000

[Volatility Bound Test]

$$\hat{\Delta} = Var(\hat{M}) - (\mathbf{1} - E[\hat{M}]E[\mathbf{R}])'\Sigma_R^{-1}(\mathbf{1} - E[\hat{M}]E[\mathbf{R}])$$

$$Z = \sqrt{T}\,\frac{\hat{\Delta}}{\hat{\sigma}_\Delta} \xrightarrow{d} N(0,1)$$

	Z1	Z2
E[M]	0.943	0.979
Var[M]	0.068	0.073
Δ (distance measure)	-115.054	-13.659
Z (Wald Statistic)	-8.241	-7.725
p-value	0.000	0.000

[Mispricing Test]

$$E\left[M_{t,t+1}\left(R^f_{t,t+1} + \phi^f\right)\right] = 1 ,$$

and $E\left[M_{t,t+1}\left(R^i_{t,t+1} - R^f_{t,t+1} + \phi^i\right)\right] = 0$ for *i*=1,...*n* th risky asset

	Z1	Z2
ϕ^{Rf}	0.058 (2.532)**	0.019 (0.742)
ϕ^{R1}	0.135E-02 (0.296)	0.372E-02 (0.787)
ϕ^{R2}	0.278E-02 (0.490)	0.582E-02 (0.944)
ϕ^{R3}	0.156E-02 (0.289)	0.383E-02 (0.665)
ϕ^{R4}	-0.388E-03 (-0.099)	0.101E-03 (0.258)
ϕ^{R5}	-0.552E-03 (-0.128)	0.197E-02 (0.411)
ϕ^{R6}	-0.406E-03 (-0.087)	0.136E-02 (0.260)
ϕ^{R7}	-0.213E-02 (-0.572)	-0.956E-04 (-0.024)
ϕ^{R8}	0.384E-02 (0.854)	0.538E-02 (1.062)
ϕ^{R9}	-0.460E-02 (-1.030)	-0.194E-02 (-0.656)
ϕ^{R10}	-0.206E-03 (-0.046)	0.172E-02 (0.351)
ϕ^{R11}	0.824E-04 (0.013)	0.210E-02 (0.301)
ϕ^{R12}	-0.590E-03 (-0.124)	0.224E-02 (0.424)
ϕ^{R13}	-0.712E-03 (-0.137)	0.119E-02 (0.222)
ϕ^{R14}	-0.116E-02 (-0.247)	0.122E-02 (0.238)
ϕ^{R15}	-0.501E-02 (-1.036)	-0.219E-02 (-0.444)
ϕ^{R16}	-0.313E-02 (-0.684)	-0.924E-03 (-0.197)
ϕ^{R17}	-0.525E-02 (-1.180)	-0.256E-02 (-0.542)
ϕ^{R18}	-0.297E-02 (-0.714)	-0.111E-02 (-0.263)
ϕ^{R19}	-0.538E-03 (-0.125)	0.178E-02 (0.389)
ϕ^{R20}	0.856E-03 (0.139)	0.208E-02 (0.327)
ϕ^{R21}	-0.724E-04 (-0.012)	0.346E-02 (0.551)
ϕ^{R22}	-0.287E-02 (-0.584)	-0.541E-03 (-0.101)
ϕ^{R23}	0.467E-02 (0.858)	0.783E-02 (1.349)
ϕ^{R24}	0.776E-03 (0.126)	0.117E-02 (0.180)
ϕ^{R25}	-0.147E-02 (-0.276)	0.110E-02 (0.194)
ϕ^{R26}	-0.470E-02 (-0.626)	-0.351E-02 (-0.450)
ϕ^{R27}	-0.844E-03 (-0.176)	-0.113E-02 (-0.266)
ϕ^{R28}	-0.122E-02 (-0.257)	0.661E-04 (0.013)

Notes: 1. Estimation is based on the unconditional version of GMM. The system is exactly identified so that unconditional sample moments are used to estimate mispricing coefficients.

2. The *t*-values are reported in parentheses (*: significant at the 10% level. **: significant at the 5% level. ***: significant at the 1% level.), which are calculated based on standard errors that are corrected for the heteroscedasticity by White's (1980) method and the autocorrelation by Newey and West's (1987) method (a lag length of 12 months is used).

(ii) Market Return and Long-Term Interest Rate

[Basic Estimation Results by GMM]

$$\text{(Z1)}\ \gamma_t^0 = -\left(\Phi^0_{Constant} + \Phi^0_{IP} IP_{t-2} + \Phi^0_{UI} UI_{t-2} + \Phi^0_{UPR} UPR_t + \Phi^0_{UTS} UTS_t\right)$$

$$\gamma_t^k = \Phi^k_{Constant} + \Phi^k_{IP} IP_{t-2} + \Phi^k_{UI} UI_{t-2} + \Phi^k_{UPR} UPR_t + \Phi^k_{UTS} UTS_t \qquad \text{for } k\text{=MKT and INT}$$

$$\text{(Z2)}\ \gamma_t^0 = -\left(\Phi^0_{Constant} + \Phi^0_{UPR} UPR_t + \Phi^0_{UTS} UTS_t\right)$$

$$\gamma_t^k = \Phi^k_{Constant} + \Phi^k_{UPR} UPR_t + \Phi^k_{UTS} UTS_t \qquad \text{for } k\text{=MKT and INT}$$

	Z1			Z2		
	γ^0	γ^{MKT}	γ^{INT}	γ^0	γ^{MKT}	γ^{INT}
$\Phi_{Constant}$	0.013	-1.364	460.812	0.048	0.163	978.308
	(1.545)	(-2.520)**	(4.392)***	(4.150)***	(0.231)	(8.091)***
Φ^j_{IP}	1.613	200.566	14422.9			
	(3.098)***	(6.570)***	(1.857)*			
Φ^j_{UI}	3.056	-1156.87	-2786.81			
	(1.143)	(-10.34)***	(-0.072)			
Φ^j_{UPR}	48.490	5011.25	-1.57E+07	2.812	4391.35	-2.55E+07
	(1.900)*	(5.418)***	(-9.219)***	(0.090)	(3.437)***	(-11.92)***
Φ^j_{UTS}	-5.780	-1124.77	237936	4.585	-1349.93	460405
	(-0.778)	(-3.468)***	(5.394)***	(0.610)	(-3.151)***	(10.20)***
J-test (χ^2)		18.180			17.850	
p-value		(0.999)			(0.999)	

Notes: 1. γ^0 is the time-varying constant, and γ^{MKT} is the price of market risk in the GMM system (15).
2. The *t*-values are reported in parentheses. (*: significant at the 10% level. **: significant at the 5% level. ***: significant at the 1% level.) The *J*-test for overidentifying restrictions is distributed χ^2.

[Hypothesis Testing (Wald Tests) on the Estimated Pricing Coefficients]

Null Hypothesis: (Z1) $\Phi^k_{Constant}=\Phi^k_{IP}=\Phi^k_{UI}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0, MKT, or INT
(Z2) $\Phi^k_{Constant}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0, MKT, or INT

	Z1			Z2		
	k=0	k=MKT	k=INT	k=0	k=MKT	k=INT
χ^2	52.195	225.186	175.644	48.672	33.417	228.716
p-value	0.000	0.000	0.000	0.000	0.000	0.000

Null Hypothesis: (Z1) $\Phi^k_{IP}=\Phi^k_{UI}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0, MKT, or INT
(Z2) $\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0, MKT, or INT

	Z1			Z2		
	k=0	k=MKT	k=INT	k=0	k=MKT	k=INT
χ^2	38.576	198.658	174.998	0.569	16.873	227.762
p-value	0.000	0.000	0.000	0.752	0.014	0.000

Null Hypothesis: (Z1) $\Phi^k_{IP}=\Phi^k_{UI}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for all k
(Z2) $\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for all k

	Z1	Z2
	k=0, MKT, & INT	k=0, MKT, & INT
χ^2	580.378	331.727
p-value	0.000	0.000

[Volatility Bound Test]

$$\hat{\Delta} = Var(\hat{M}) - (\mathbf{1} - E[\hat{M}]E[\mathbf{R}])'\Sigma_R^{-1}(\mathbf{1} - E[\hat{M}]E[\mathbf{R}])$$

$$Z = \sqrt{T}\,\frac{\hat{\Delta}}{\hat{\sigma}_\Delta} \xrightarrow{d} N(0,1)$$

	Z1	Z2
E[M]	0.957	0.976
Var[M]	0.058	0.086
Δ (distance measure)	-63.258	-17.780
Z (Wald Statistic)	-8.172	-7.849
p-value	0.000	0.000

[Mispricing Test]

$$E\left[M_{t,t+1}\left(R^f_{t,t+1} + \phi^f\right)\right] = 1,$$

and $E\left[M_{t,t+1}\left(R^i_{t,t+1} - R^f_{t,t+1} + \phi^i\right)\right] = 0$ for i=1,...n th risky asset

	Z1	Z2
ϕ^{Rf}	0.043 (2.528)**	0.022 (0.964)
ϕ^{R1}	0.224E-02 (0.468)	0.291E-02 (0.596)
ϕ^{R2}	0.380E-02 (0.629)	0.543E-02 (0.876)
ϕ^{R3}	0.151E-02 (0.263)	0.238E-02 (0.409)
ϕ^{R4}	-0.833E-03 (-0.194)	-0.587E-03 (-0.137)
ϕ^{R5}	0.720E-04 (0.015)	0.119E-02 (0.244)
ϕ^{R6}	-0.138E-04 (-0.003)	0.923E-03 (0.182)
ϕ^{R7}	-0.232E-02 (-0.568)	-0.176E-02 (-0.431)
ϕ^{R8}	0.465E-02 (1.038)	0.546E-02 (1.147)
ϕ^{R9}	-0.337E-02 (-0.716)	-0.275E-02 (-0.622)
ϕ^{R10}	-0.396E-04 (-0.008)	0.796E-03 (0.157)
ϕ^{R11}	0.121E-02 (0.190)	0.206E-02 (0.304)
ϕ^{R12}	0.907E-03 (0.181)	0.161E-02 (0.309)
ϕ^{R13}	0.159E-03 (0.030)	0.954E-03 (0.180)
ϕ^{R14}	0.574E-03 (0.117)	0.197E-02 (0.398)
ϕ^{R15}	-0.309E-02 (-0.615)	-0.158E-02 (-0.309)
ϕ^{R16}	-0.167E-02 (-0.339)	-0.819E-03 (-0.165)
ϕ^{R17}	-0.325E-02 (-0.666)	-0.174E-02 (-0.352)
ϕ^{R18}	-0.223E-02 (-0.506)	-0.164E-02 (-0.378)
ϕ^{R19}	0.138E-03 (0.030)	0.953E-03 (0.205)
ϕ^{R20}	-0.687E-03 (-0.110)	-0.104E-02 (-0.166)
ϕ^{R21}	0.116E-03 (0.019)	0.816E-03 (0.132)
ϕ^{R22}	-0.248E-02 (-0.467)	-0.133E-02 (-0.241)
ϕ^{R23}	0.780E-02 (1.342)	0.875E-02 (1.491)
ϕ^{R24}	0.150E-02 (0.236)	0.106E-02 (0.161)
ϕ^{R25}	-0.533E-03 (-0.101)	0.874E-03 (0.167)
ϕ^{R26}	-0.348E-02 (-0.438)	-0.295E-02 (-0.383)
ϕ^{R27}	-0.169E-02 (-0.337)	-0.313E-02 (-0.637)
ϕ^{R28}	-0.847E-03 (-0.168)	-0.740E-03 (-0.143)

Notes: 1. Estimation is based on the unconditional version of GMM. The system is exactly identified so that unconditional sample moments are used to estimate mispricing coefficients.

2. The *t*-values are reported in parentheses (*: significant at the 10% level. **: significant at the 5% level. ***: significant at the 1% level.), which are calculated based on standard errors that are corrected for the heteroscedasticity by White's (1980) method and the autocorrelation by Newey and West's (1987) method (a lag length of 12 months is used).

(iii) Foreign Exchange Rate and Long-Term Interest Rate

[Basic Estimation Results by GMM]

(Z1) $\gamma_t^0 = -\left(\Phi_{Constant}^0 + \Phi_{IP}^0 IP_{t-2} + \Phi_{UI}^0 UI_{t-2} + \Phi_{UPR}^0 UPR_t + \Phi_{UTS}^0 UTS_t\right)$

$\gamma_t^k = \Phi_{Constant}^k + \Phi_{IP}^k IP_{t-2} + \Phi_{UI}^k UI_{t-2} + \Phi_{UPR}^k UPR_t + \Phi_{UTS}^k UTS_t$ for k=EX and INT

(Z2) $\gamma_t^0 = -\left(\Phi_{Constant}^0 + \Phi_{UPR}^0 UPR_t + \Phi_{UTS}^0 UTS_t\right)$

$\gamma_t^k = \Phi_{Constant}^k + \Phi_{UPR}^k UPR_t + \Phi_{UTS}^k UTS_t$ for k=EX and INT

	Z1			Z2		
	γ^0	γ^{EX}	γ^{INT}	γ^0	γ^{EX}	γ^{INT}
$\Phi_{Constant}$	-0.140	-2.723	249.626	0.055	0.481	662.726
	(-13.05)***	(-1.894)*	(2.219)**	(2.822)***	(0.207)	(4.983)***
Φ^j_{IP}	-0.523	-217.170	5691.17			
	(-1.007)	(-2.821)***	(0.759)			
Φ^j_{UI}	24.441	-5319.09	-109254			
	(9.123)***	(-14.44)***	(-3.301)***			
Φ^j_{UPR}	-121.132	3345.16	-573302	103.832	17527.7	-1.86E+07
	(-4.534)***	(1.598)	(-3.307)***	(2.240)**	(4.731)***	(-7.579)***
Φ^j_{UTS}	84.997	286.422	425142	-36.988	-4549.71	319945
	(10.71)***	(0.430)	(8.133)***	(-2.925)***	(-3.828)***	(4.913)***
J-test (χ^2)		18.151			17.805	
p-value		(0.999)			(0.999)	

Notes: 1. γ^0 is the time-varying constant, and γ^{MKT} is the price of market risk in the GMM system (15).
2. The t-values are reported in parentheses. (*: significant at the 10% level. **: significant at the 5% level. ***: significant at the 1% level.) The J-test for overidentifying restrictions is distributed χ^2.

[Hypothesis Testing (Wald Tests) on the Estimated Pricing Coefficients]

Null Hypothesis: (Z1) $\Phi^k_{Constant}=\Phi^k_{IP}=\Phi^k_{UI}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0, EX, or INT
(Z2) $\Phi^k_{Constant}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0, EX, or INT

	Z1			Z2		
	k=0	k=EX	k=INT	k=0	k=EX	k=INT
χ^2	557.058	300.993	157.222	48.980	49.258	73.497
p-value	0.000	0.000	0.000	0.000	0.000	0.000

Null Hypothesis: (Z1) $\Phi^k_{IP}=\Phi^k_{UI}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0, EX, or INT
(Z2) $\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0, EX, or INT

	Z1			Z2		
	k=0	k=EX	k=INT	k=0	k=EX	k=INT
χ^2	175.902	278.102	98.348	10.742	30.222	71.986
p-value	0.000	0.000	0.000	0.000	0.000	0.000

Null Hypothesis: (Z1) $\Phi^k_{IP}=\Phi^k_{UI}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for all k
(Z2) $\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for all k

	Z1	Z2
	k=0, EX, & INT	k=0, EX, & INT
χ^2	642.441	246.095
p-value	0.000	0.000

[Volatility Bound Test]

$$\hat{\Delta} = Var(\hat{M}) - (\mathbf{1} - E[\hat{M}]E[\mathbf{R}])'\Sigma_R^{-1}(\mathbf{1} - E[\hat{M}]E[\mathbf{R}])$$

$$Z = \sqrt{T}\,\frac{\hat{\Delta}}{\hat{\sigma}_{\Delta}} \xrightarrow{d} N(0,1)$$

	Z1	Z2
E[M]	0.880	0.982
Var[M]	0.085	0.078
Δ (distance measure)	-529.915	-9.298
Z (Wald Statistic)	-8.326	-7.494
p-value	0.000	0.000

[Mispricing Test]

$$E\left[M_{t,t+1}\left(R^f_{t,t+1} + \phi^f\right)\right] = 1\,,$$

and $E\left[M_{t,t+1}\left(R^i_{t,t+1} - R^f_{t,t+1} + \phi^i\right)\right] = 0$ for i=1,...n th risky asset

	Z1	Z2
ϕ^{Rf}	0.135 (3.894)***	0.016 (0.759)
ϕ^{R1}	0.494E-03 (0.103)	0.764E-03 (0.169)
ϕ^{R2}	0.197E-02 (0.554)	0.257E-02 (0.432)
ϕ^{R3}	0.168E-02 (0.329)	0.746E-04 (0.013)
ϕ^{R4}	-0.823E-03 (-0.207)	-0.190E-02 (-0.481)
ϕ^{R5}	-0.276E-03 (-0.063)	-0.890E-03 (-0.200)
ϕ^{R6}	-0.530E-03 (-0.112)	-0.925E-03 (-0.190)
ϕ^{R7}	-0.236E-02 (-0.653)	-0.352E-02 (-0.972)
ϕ^{R8}	0.343E-02 (0.749)	0.310E-02 (0.666)
ϕ^{R9}	-0.440E-02 (-1.107)	-0.574E-02 (-1.408)
ϕ^{R10}	0.209E-03 (0.045)	-0.112E-02 (-0.244)
ϕ^{R11}	0.116E-02 (0.176)	-0.891E-03 (-0.135)
ϕ^{R12}	-0.198E-02 (-0.409)	-0.964E-03 (-0.205)
ϕ^{R13}	-0.458E-04 (-0.009)	-0.108E-02 (-0.210)
ϕ^{R14}	-0.104E-03 (-0.024)	-0.101E-02 (-0.217)
ϕ^{R15}	-0.414E-02 (-0.864)	-0.443E-02 (-0.944)
ϕ^{R16}	-0.277E-02 (-0.608)	-0.339E-02 (-0.744)
ϕ^{R17}	-0.473E-02 (-1.089)	-0.426E-02 (-0.967)
ϕ^{R18}	-0.310E-02 (-0.747)	-0.367E-02 (-0.934)
ϕ^{R19}	-0.603E-03 (-0.140)	-0.107E-02 (-0.245)
ϕ^{R20}	-0.861E-03 (-0.141)	-0.286E-02 (-0.473)
ϕ^{R21}	-0.900E-03 (-0.153)	-0.216E-02 (-0.366)
ϕ^{R22}	-0.274E-02 (-0.542)	-0.355E-02 (-0.679)
ϕ^{R23}	0.372E-02 (0.640)	0.515E-02 (0.931)
ϕ^{R24}	-0.727E-02 (-0.113)	-0.736E-03 (-0.118)
ϕ^{R25}	-0.114E-02 (-0.235)	-0.180E-02 (-0.343)
ϕ^{R26}	-0.584E-02 (-0.785)	-0.509E-02 (-0.697)
ϕ^{R27}	-0.203E-02 (-0.447)	-0.446E-02 (-0.927)
ϕ^{R28}	-0.172E-02 (-0.342)	-0.260E-02 (-0.544)

Notes: 1. Estimation is based on the unconditional version of GMM. The system is exactly identified so that unconditional sample moments are used to estimate mispricing coefficients.

2. The *t*-values are reported in parentheses (*: significant at the 10% level. **: significant at the 5% level. ***: significant at the 1% level.), which are calculated based on standard errors that are corrected for the heteroscedasticity by White's (1980) method and the autocorrelation by Newey and West's (1987) method (a lag length of 12 months is used).

Table 7: Estimation of the Conditional Three-Factor APT (March 1980-December 1998)

[Basic Estimation Results by GMM]

(Z1) $\gamma_t^0 = -\left(\Phi_{Constant}^0 + \Phi_{IP}^0 IP_{t-2} + \Phi_{UI}^0 UI_{t-2} + \Phi_{UPR}^0 UPR_t + \Phi_{UTS}^0 UTS_t\right)$

$\gamma_t^k = \Phi_{Constant}^k + \Phi_{IP}^k IP_{t-2} + \Phi_{UI}^k UI_{t-2} + \Phi_{UPR}^k UPR_t + \Phi_{UTS}^k UTS_t$ for k=MKT, EX and INT

(Z2) $\gamma_t^0 = -\left(\Phi_{Constant}^0 + \Phi_{UPR}^0 UPR_t + \Phi_{UTS}^0 UTS_t\right)$

$\gamma_t^k = \Phi_{Constant}^k + \Phi_{UPR}^k UPR_t + \Phi_{UTS}^k UTS_t$ for k=MKT, EX and INT

	Z1				Z2			
	γ^0	γ^{MKT}	γ^{EX}	γ^{INT}	γ^0	γ^{MKT}	γ^{EX}	γ^{INT}
$\Phi_{Constant}$	-0.068	-1.650	0.913	496.562	0.055	0.577	-1.528	1075.66
	(-5.04)***	(-2.95)***	(0.55)	(4.32)***	(2.65)	(0.83)	(-0.634)	(8.28)***
Φ^j_{IP}	1.536	191.471	-264.745	498.742				
	(2.00)**	(5.37)***	(-2.91)***	(0.06)				
Φ^j_{UI}	14.361	-740.436	-4373.11	-120962				
	(4.05)***	(-5.50)***	(-10.8)***	(-3.22)***				
Φ^j_{UPR}	31.174	3434.35	5053.71	-1.16E+06	17.038	3888.29	10068.2	-2.4E+06
	(1.03)	(3.42)***	(2.30)**	(-6.24)***	(0.35)	(2.93)***	(2.62)***	(-10.2)***
Φ^j_{UTS}	20.548	-659.643	-811.474	331624	-8.607	-1528.13	-4541.36	287004
	(2.22)**	(-1.99)**	(-1.00)	(6.36)***	(-0.72)	(-3.68)***	(-3.81)***	(4.78)***
J-test	18.162				17.805			
p-value	(0.999)				(0.999)			

Notes: 1. γ^0 is the time-varying constant, and γ^{MKT} is the price of market risk in the GMM system (15).
2. The t-values are reported in parentheses. (*: significant at the 10% level. **: significant at the 5% level. ***: significant at the 1% level.) The J-test for overidentifying restrictions is distributed χ^2.

[Hypothesis Testing (Wald Tests) on the Estimated Pricing Coefficients]

Null Hypothesis: (Z1) $\Phi^k_{Constant}=\Phi^k_{IP}=\Phi^k_{UI}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0, MKT, EX, or INT
(Z2) $\Phi^k_{Constant}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0, MKT, EX, or INT

	Z1				Z2			
	k=0	k=MKT	k=EX	k=INT	k=0	k=MKT	k=EX	k=INT
χ^2	60.348	97.165	222.353	149.307	31.237	39.224	20.696	121.691
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.000

Null Hypothesis: (Z1) $\Phi^k_{IP}=\Phi^k_{UI}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0, MKT, EX or INT
(Z2) $\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for k=0, MKT, EX or INT

	Z1				Z2			
	k=0	k=MKT	k=EX	k=INT	k=0	k=MKT	k=EX	k=INT
χ^2	40.817	91.325	163.126	108.611	0.541	17.485	18.035	113.828
p-value	0.000	0.000	0.000	0.000	0.763	0.009	0.007	0.000

Null Hypothesis: (Z1) $\Phi^k_{IP}=\Phi^k_{UI}=\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for all k
(Z2) $\Phi^k_{UPR}=\Phi^k_{UTS}=0$ for all k

	Z1	Z2
	k=0, MKT, EX & INT	k=0, MKT, EX & INT
χ^2	543.793	295.113
p-value	0.000	0.000

[Volatility Bound Test]

$$\hat{\Delta} = Var(\hat{M}) - (\mathbf{1} - E[\hat{M}]E[\mathbf{R}])'\Sigma_R^{-1}(\mathbf{1} - E[\hat{M}]E[\mathbf{R}])$$

$$Z = \sqrt{T}\,\frac{\hat{\Delta}}{\hat{\sigma}_\Delta} \xrightarrow{d} N(0,1)$$

	Z1	Z2
E[M]	0.923	0.967
Var[M]	0.086	0.088
Δ (distance measure)	-211.204	-34.793
Z (Wald Statistic)	-8.286	-8.050
p-value	0.000	0.000

[Mispricing Test]

$$E\left[M_{t,t+1}\left(R_{t,t+1}^f + \phi^f\right)\right] = 1\,,$$

and $\quad E\left[M_{t,t+1}\left(R_{t,t+1}^i - R_{t,t+1}^f + \phi^i\right)\right] = 0 \qquad$ for i=1,...n th risky asset

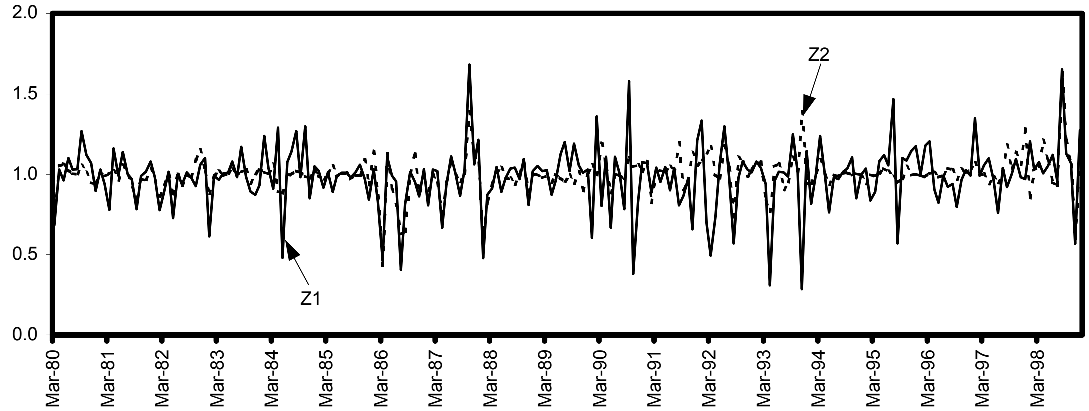
	Z1	Z2
ϕ^{Rf}	0.081 (2.902)***	0.031 (1.338)
ϕ^{R1}	0.105E-02 (0.217)	0.194E-02 (0.596)
ϕ^{R2}	0.331E-02 (0.582)	0.573E-02 (0.915)
ϕ^{R3}	0.141E-02 (0.260)	0.243E-02 (0.408)
ϕ^{R4}	-0.776E-03 (-0.186)	-0.378E-04 (-0.009)
ϕ^{R5}	-0.553E-03 (-0.121)	0.138E-02 (0.276)
ϕ^{R6}	-0.316E-03 (-0.067)	0.739E-03 (0.142)
ϕ^{R7}	-0.258E-02 (-0.654)	-0.111E-02 (-0.260)
ϕ^{R8}	0.442E-02 (0.979)	0.500E-02 (1.038)
ϕ^{R9}	-0.421E-02 (-0.940)	-0.242E-02 (-0.517)
ϕ^{R10}	-0.164E-03 (-0.034)	0.116E-02 (0.222)
ϕ^{R11}	0.697E-03 (0.108)	0.193E-02 (0.279)
ϕ^{R12}	-0.876E-03 (-0.176)	0.199E-02 (0.369)
ϕ^{R13}	-0.418E-03 (-0.081)	0.113E-02 (0.208)
ϕ^{R14}	-0.482E-03 (-0.103)	0.244E-02 (0.471)
ϕ^{R15}	-0.441E-02 (-0.863)	-0.813E-03 (-0.158)
ϕ^{R16}	-0.271E-02 (-0.551)	-0.345E-03 (-0.068)
ϕ^{R17}	-0.479E-02 (-1.021)	-0.790E-03 (-0.158)
ϕ^{R18}	-0.330E-02 (-0.758)	-0.906E-03 (-0.203)
ϕ^{R19}	-0.657E-03 (-0.147)	0.133E-02 (0.277)
ϕ^{R20}	-0.270E-03 (-0.043)	-0.742E-03 (-0.117)
ϕ^{R21}	-0.105E-02 (-0.173)	0.115E-02 (0.180)
ϕ^{R22}	-0.294E-02 (-0.566)	-0.105E-02 (-0.183)
ϕ^{R23}	0.510E-02 (0.880)	0.868E-02 (1.444)
ϕ^{R24}	0.380E-03 (0.058)	0.113E-02 (0.174)
ϕ^{R25}	-0.119E-02 (-0.232)	0.629E-03 (0.115)
ϕ^{R26}	-0.428E-02 (-0.569)	-0.275E-02 (-0.350)
ϕ^{R27}	-0.145E-02 (-0.302)	-0.319E-02 (-0.632)
ϕ^{R28}	-0.164E-02 (-0.325)	-0.174E-03 (-0.034)

Notes: 1. Estimation is based on the unconditional version of GMM. The system is exactly identified so that unconditional sample moments are used to estimate mispricing coefficients.

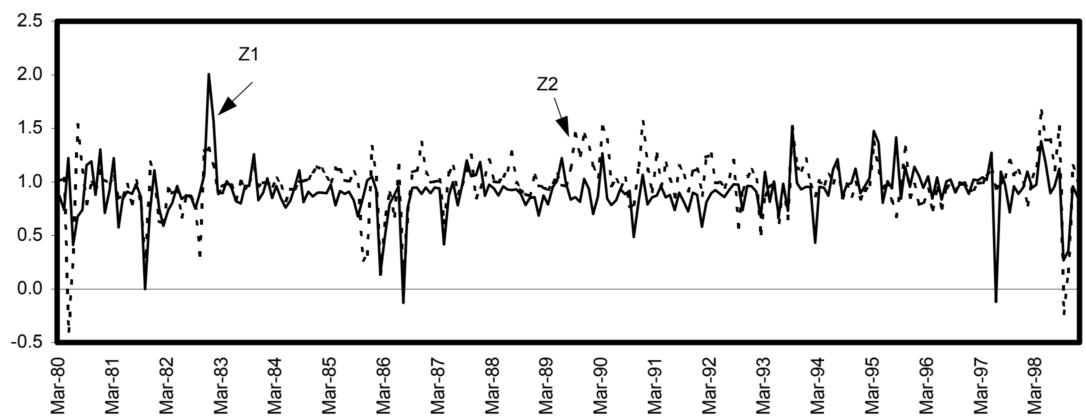
2. The *t*-values are reported in parentheses (*: significant at the 10% level. **: significant at the 5% level. ***: significant at the 1% level.), which are calculated based on standard errors that are corrected for the heteroscedasticity by White's (1980) method and the autocorrelation by Newey and West's (1987) method (a lag length of 12 months is used).

Figure 1: Stochastic Discount Factors Implied by One-Factor Models

(i) Market Return



(ii) Foreign Exchange Rate



(iii) Long-Term Interest Rate

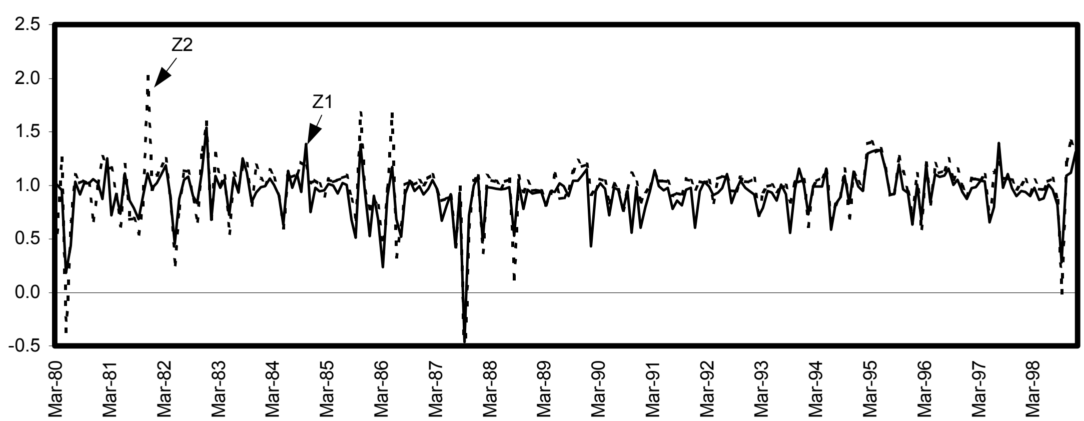
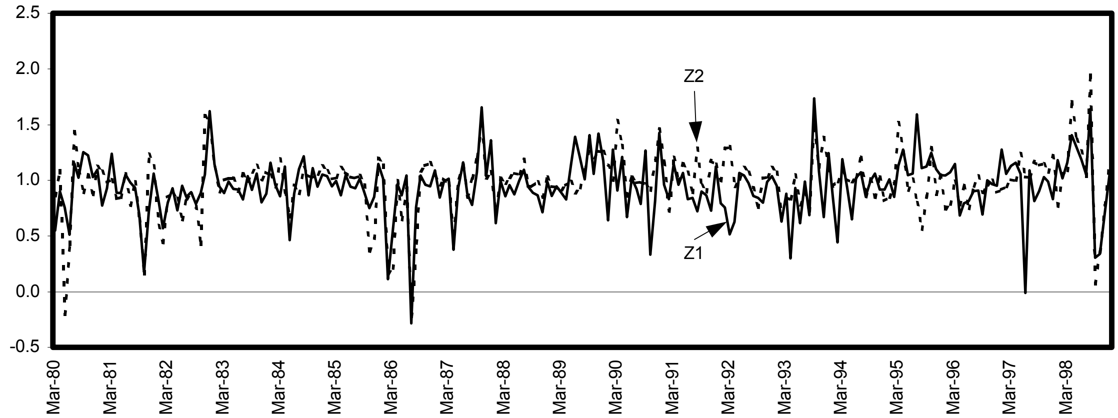
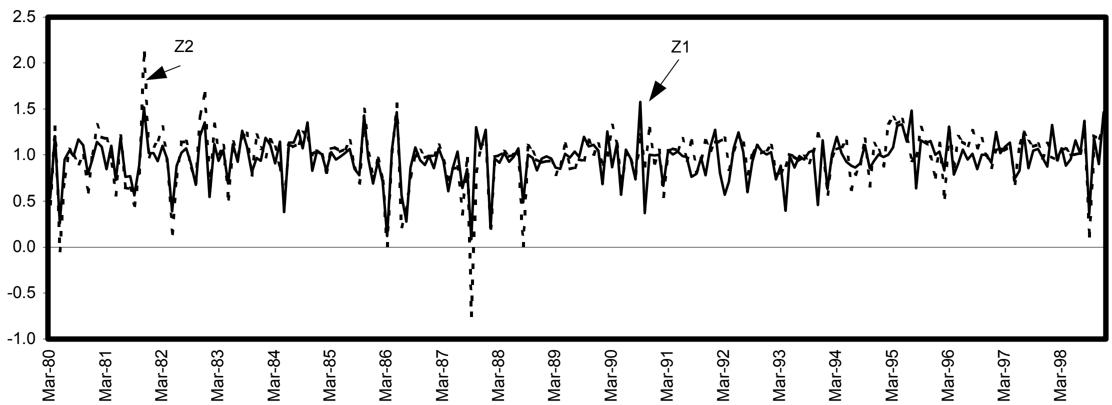


Figure 2: Stochastic Discount Factors Implied by Two-Factor Models

(i) Market Return and Foreign Exchange Rate



(ii) Market Return and Long-Term Interest Rate



(iii) Foreign Exchange Rate and Long-Term Interest Rate

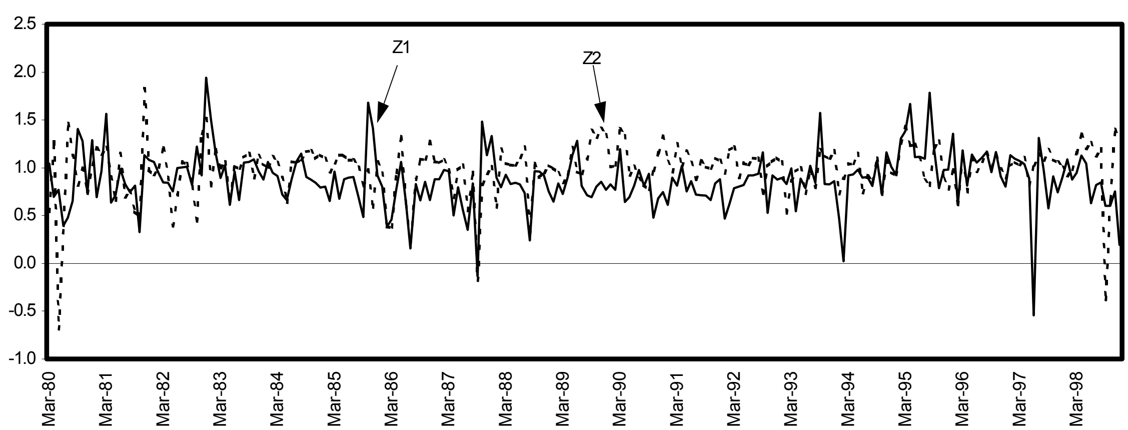


Figure 3: Stochastic Discount Factors Implied by Three-Factor Models

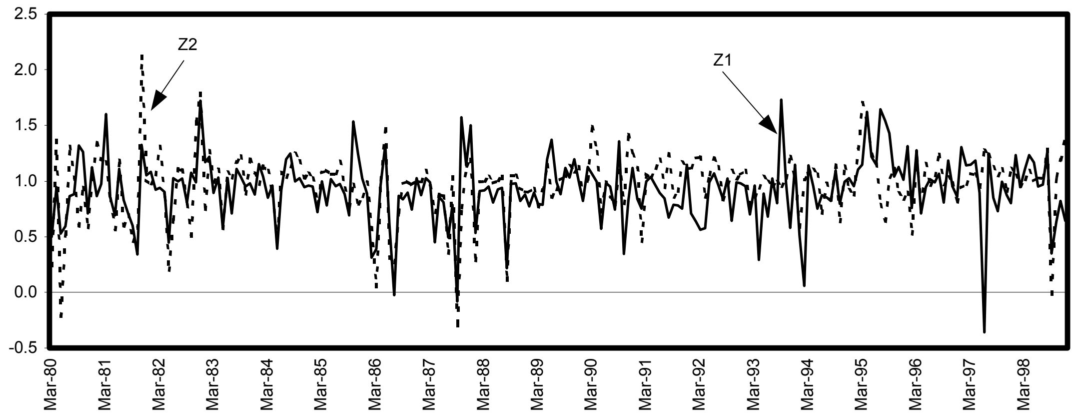
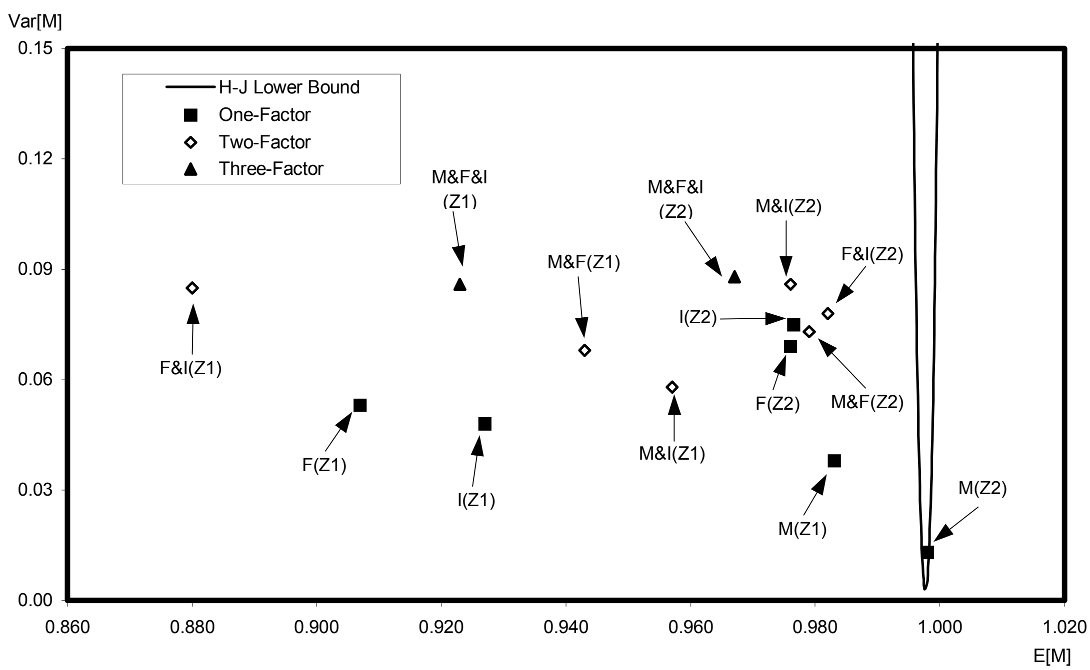


Figure 4: Hansen and Jagannathan's Lower Volatility Bound



Notes: 1. Hansen and Jagannathan's lower volatility bound is computed based on a portfolio consisting of the real value-weighted stock market return and the real risk-free interest rate.

2. In the diagram, M represents the market return in excess of the risk-free interest rate, F the foreign exchange rate, and I the long-term interest rate. Z1 and Z2 indicate the information set, respectively.