The time-varying pricing of value and size premia in Japan*

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Abstract

Following Fama and French's (1996) suggestion of the equivalence of their three-factor model and established equilibrium pricing models, this paper examines whether the Fama–French small-minus-big (SMB) and high-minus-low (HML) factors mimic the state variables in Merton's (1973) intertemporal capital asset pricing model (ICAPM). We test this equivalence for the Japanese stock market over the period 1982 to 2003 using a multivariate Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model. Our direct test of the time-varying pricing of the Fama–French factors in the ICAPM finds that both SMB and HML play the role of well-priced state variables. Our findings thus support the suggestion that SMB and HML factors indeed mimic the state variables in Merton's ICAPM in Japan.

Key Words: Conditional CAPM; Fama–French model; Multivariate GARCH Model; Panel data analysis; Time-varying price of risk.
JEL Classification: G12; G15.

1 Introduction

What is the role of Fama and French's (1993) small-minus-big (SMB) and high-minus-low (HML) factors in equity markets? Fama and French (1996, p.57) suggested that "···*the empirical successes of the Fama–French model suggest that it is an equilibrium pricing model, a three-factor version of Merton's (1973) intertemporal capital asset pricing model (ICAPM) or Ross's (1976) arbitrage pricing theory (APT). In this view, SMB and HML mimic combinations of two underlying risk factors or state variables of special hedging concern to investors*". Subsequent to Fama and French (1996), several studies, including Liew and Vassalou (2000) and Petkova (2006), investi-

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gated the role of the SMB and HML factors.[1] However, as far as the authors are aware, there is no known research that directly tests whether SMB and HML mimic the state variables in the ICAPM strictly using Merton's (1973) framework. Therefore, the objective of this paper is to empirically test this proposition by examining the pricing of SMB and HML as state variables strictly in the context of Merton's (1973) ICAPM. The multivariate Generalized Autoregressive Conditional Heteroskedasticity (GARCH) approach employed for this purpose enables us to perform the test more directly because with it we obtain the conditional covariance risk of SMB and HML. If SMB and HML mimic the state variables in the ICAPM, they should be priced in the ICAPM framework. Moreover, despite the effectiveness of the multivariate GARCH model in asset pricing, its application to asset pricing models in the existing literature is limited. Thus, our approach is relatively novel.[2]

From a technical point of view, we incorporate time-varying risk prices into our analysis. This is another interesting characteristic of our approach since many existing studies, such as Harvey (1989), Ng (1991), and Zhou (1994), take into account only time-varying risk.[3]

The contribution of this paper is as follows. First, both our monthly and panel data analysis of time-varying risk pricing reveals that the SMB is a well priced state variable in the context of Merton's (1973) ICAPM. Second, both our monthly and panel data analysis of time-varying risk pricing also finds that the HML is also generally a priced state variable in the framework of Merton's (1973) ICAPM. Third, from the viewpoint of model evaluation, our formal F-tests indicate that the conditional Fama–French model is indeed better than the conditional CAPM. This also supports Fama and French (1996) because it shows the effectiveness of SMB and HML in the ICAPM. Finally, and as an ancillary finding, we find that the conditional covariance market risk in the CAPM, as derived by the multivariate GARCH model, is strongly priced in Japan. This result is also interesting because in many studies, including Fama and French (2006), and Lewellen and

[1] Petkova (2006) found that the SMB and HML are correlated with innovations in variables that would describe investment opportunity in the context of Merton's ICAPM. Liew and Vassalou (2000) considered that GDP growth is representative of the investment opportunities in Merton's ICAPM, and found that HML and SMB are linked to future GDP growth in ten major international countries. That is to say, both studies tested whether SMB and HML are related with variables that would describe investment opportunities in Merton's (1973) ICAPM. We consider these as *indirect* tests of the proposition suggested by Fama and French (1996).

[2] Studies using multivariate GARCH models include, for example, Beine (2004), Tai (2004), Audrino and Barone-Adesi (2005), Christiansen (2005), Ewing and Malik (2005), Giamouridis and Vrontos (2007), and Leon et al. (2007). However, the multivariate GARCH models in this body of work, with the exception of Leon et al. (2007), are generally not employed in asset pricing models of stock returns. As for the remaining studies, Beine (2004) examines foreign exchange markets, Tai (2004) addresses contagion during the 1997 Asian crisis, Audrino and Barone-Adesi (2005) focus on the estimation and forecasting of volatility, Christiansen (2005) analyses term structure models, Ewing and Malik (2005) examine 'spillover effects' in financial markets, and Giamouridis and Vrontos (2007) consider hedge fund portfolios.

[3] The time-varying characteristics of both covariance risk and the price of risk are clearly crucial for asset pricing. There is substantial empirical evidence that the level of risk varies over time (see Bollerslev et al. (1988), Harvey (1989), Ng (1991), and Zhou (1994), amongst others). However, in many earlier studies, including Harvey (1989), Campbell (1996), Hansson and Hördahl (1998), and Guo (2006), covariance risk is regarded as time varying, but the price of risk is considered constant for a particular period. Other analyses that deal with the price of risk include Friend and Westerfield (1981), Sauer and Murphy (1992), Ferson and Harvey (1994), Priestley (1996), Flannery et al. (1997), Doukas et al. (1999), Gibson and Mougeot (2004), and Leon et al. (2007). These studies also generally assume that the price of risk is constant for a specific period. While Polk et al. (2006) undertake an empirical analysis that exploits the price of risk, their aim and approach differ from our study.

Nagel (2006), the applicability of CAPM is often in refute.

The remainder of the paper is organized as follows. Section 2 describes the conditional asset pricing models to be tested. Section 3 details the methodology and Section 4 describes the data. The empirical results and their interpretation are supplied in Sections 5 and 6. Section 7 presents some conclusions.

2 Model

To start with, Cochrane (2005) expresses Merton's (1973) ICAPM as:

$$E_t(R^i_{t+1}) - R^f_t \approx rra_t\ cov_t(R^i_{t+1}, \Delta W_{t+1}/W_t) + \lambda_{zt} cov_t(R^i_{t+1}, \Delta z_{t+1}), \tag{1}$$

where $E_t(R^i_{t+1})$ is the conditional expected return of asset i, R^f_t is the risk-free rate, rra_t is the relative risk aversion coefficient,[4] $cov_t(R^i_{t+1}, \Delta W_{t+1}/W_t)$ is the conditional covariance between the return of asset i and the change in wealth (or return on the market portfolio), $cov_t(R^i_{t+1}, \Delta z_{t+1})$ is the conditional covariance between the return of asset i and the change in state variable z, and λ_{zt} is the risk price for the state variable.

Thus, following Cochrane's (2005) expression (1), we test the pricing of the market factor, SMB and HML in the framework of Merton's ICAPM. First, we begin by setting our first model as the following conditional CAPM. The model for period t is an equilibrium relation for the conditional expected return of an asset in excess of the risk-free rate when agents use the information available at the end of period $t-1$:

$$\begin{aligned} E\left[(r_{i,t} - r_{f,t})|\Omega_{t-1}\right] &= \frac{E\left[(r_{m,t} - r_{f,t})|\Omega_{t-1}\right]}{Var\left[r_{m,t}|\Omega_{t-1}\right]} Cov\left[r_{i,t}, r_{m,t}|\Omega_{t-1}\right] && (2)\\ &= \beta_{i,t} E\left[(r_{m,t} - r_{f,t})|\Omega_{t-1}\right]. \\ \beta_{i,t} &\equiv \frac{Cov\left[r_{i,t}, r_{m,t}|\Omega_{t-1}\right]}{Var\left[r_{m,t}|\Omega_{t-1}\right]}, && (3) \end{aligned}$$

where $r_{i,t}$ and $r_{m,t}$ are the one-period returns on an asset i and the market portfolio, respectively, $r_{f,t}$ is the one-period risk-free rate, and Ω_{t-1} is the information available to the market at time $t-1$. From a cross-sectional perspective, this model implies that the conditional expected excess returns vary with the different conditional beta values or different conditional covariances. From a time-series perspective, the model has an implication that the conditional expected excess returns change over time with three time-varying components: the conditional market risk premium, the market conditional variance, and the conditional covariance between the asset's return and the market's

[4] As shown in equation (1), the time-varying characteristics of the risk price are important. Time-varying risk aversion is particularly focused upon in Able (1990), Constantinides (1990), Campbell and Cochrane (1999), Chen and Pakoš (2006), Coudert and Gex (2006), Li (2007), and Maio (2007).

return. Unlike Harvey (1989), Engel et al. (1995), and Hansson and Hördahl (1998), among others, we assume that the market price of risk is time varying rather than stable:

$$\delta_{m,t} \equiv \frac{E\left[(r_{m,t} - r_{f,t})|\Omega_{t-1}\right]}{Var\left[r_{m,t}|\Omega_{t-1}\right]}. \tag{4}$$

Thus, and differently to other studies, we use the following conditional ICAPM for a single asset i for our first model, referred to as Model 1:[5]

$$E\left[(r_{i,t} - r_{f,t})|\Omega_{t-1}\right] = \delta_{m,t}Cov\left[r_{i,t}, r_{m,t}|\Omega_{t-1}\right]. \tag{5}$$

In this formulation, the estimation of the time-varying covariance, $Cov[r_{i,t}, r_{m,t}|\Omega_{t-1}]$, is necessary for evaluating the model. By inspecting the statistical significance of $\delta_{m,t}$ using these covariances, we can judge whether the covariance market risk is priced. Thus, tests using Model 1 are the first method of analysis for our empirical work. We also use models (6) and (7) below to test our focus, namely the pricing of the Fama–French SMB and HML factors, respectively.

$$E\left[(r_{i,t} - r_{f,t})|\Omega_{t-1}\right] = \delta_{smb,t}Cov\left[r_{i,t}, r_{smb,t}|\Omega_{t-1}\right], \tag{6}$$

$$E\left[(r_{i,t} - r_{f,t})|\Omega_{t-1}\right] = \delta_{hml,t}Cov\left[r_{i,t}, r_{hml,t}|\Omega_{t-1}\right], \tag{7}$$

where $\delta_{smb,t}$: the time-varying risk price of SMB factor returns, $Cov[r_{i,t}, r_{smb,t}|\Omega_{t-1}]$: the conditional covariance between asset returns and SMB factor returns, $r_{smb,t}$, $\delta_{hml,t}$: the time-varying risk price of HML factor returns, $Cov[r_{i,t}, r_{hml,t}|\Omega_{t-1}]$: the conditional covariance between asset returns and HML factor returns, $r_{hml,t}$.

For our second model, Model 2, and in reference to (8) below, we add $Cov[r_{i,t}, r_{smb,t}|\Omega_{t-1}]$ to Model 1:

$$E\left[(r_{i,t} - r_{f,t})|\Omega_{t-1}\right] = \delta_{m,t}Cov\left[r_{i,t}, r_{m,t}|\Omega_{t-1}\right] + \delta_{smb,t}Cov\left[r_{i,t}, r_{smb,t}|\Omega_{t-1}\right]. \tag{8}$$

For our third model, Model 3, and as described in (9) below, we add $Cov[r_{i,t}, r_{hml,t}|\Omega_{t-1}]$ to Model 1:

$$E\left[(r_{i,t} - r_{f,t})|\Omega_{t-1}\right] = \delta_{m,t}Cov\left[r_{i,t}, r_{m,t}|\Omega_{t-1}\right] + \delta_{hml,t}Cov\left[r_{i,t}, r_{hml,t}|\Omega_{t-1}\right]. \tag{9}$$

Finally, our last model, Model 4, yields the following three-factor model (10) which can be interpreted as a version of Merton's (1973) ICAPM including Fama–French factors:

[5] Model 1 is also considered as a generalization of the one-period CAPM developed by Sharp (1964)–Lintner (1965)–Mossin (1966). Other studies concerning the conditional CAPM include Jagannathan and Wang (1996), Lettau and Ludvigson (2001), Ang and Chen (2007), and Petkova and Zhang (2005).

$$
\begin{aligned}
E\left[(r_{i,t}-r_{f,t})|\Omega_{t-1}\right] \quad = \quad & \delta_{m,t}Cov\left[r_{i,t},r_{m,t}|\Omega_{t-1}\right] \\
& +\delta_{smb,t}Cov\left[r_{i,t},r_{smb,t}|\Omega_{t-1}\right]+\delta_{hml,t}Cov\left[r_{i,t},r_{hml,t}|\Omega_{t-1}\right]. \qquad (10)
\end{aligned}
$$

3 Methodology

As argued in the excellent survey by Bauwens et al. (2006), the multivariate GARCH model is crucially important in the context of asset pricing because the model is very useful for calculating the time-varying covariances or factor loadings.

To evaluate the time-varying risk prices, $\delta_{m,t}$, $\delta_{smb,t}$, and $\delta_{hml,t}$ detailed earlier, we first estimate the time-varying covariances, $Cov[r_{i,t},r_{m,t}|\Omega_{t-1}]$, $Cov[r_{i,t},r_{smb,t}|\Omega_{t-1}]$, and $Cov[r_{i,t},r_{hml,t}|\Omega_{t-1}]$, with the multivariate BEKK (Engle and Kroner (1995)) GARCH model. This particular model ensures that the $\boldsymbol{H}$ matrix is always positive definite, and is specified by:

$$
\boldsymbol{H_t}=\boldsymbol{W}+\boldsymbol{B'H_{t-1}B}+\boldsymbol{A'\Xi_{t-1}\Xi'_{t-1}A}, \qquad (11)
$$

where $\boldsymbol{W}$, $\boldsymbol{A}$, and $\boldsymbol{B}$ are 2×2 matrices of parameters, and $\boldsymbol{W}$ is assumed to be symmetric and positive definite.

For the purpose of clarity, in the case of two assets, we define the matrices as follows:

$$
\boldsymbol{H_t}=\begin{bmatrix} h_{11,t} & h_{12,t} \\ h_{12,t} & h_{22,t}\end{bmatrix},\ \boldsymbol{W}=\begin{bmatrix} w_{11} & w_{12} \\ w_{12} & w_{22}\end{bmatrix},\ \boldsymbol{A}=\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22}\end{bmatrix},
$$
$$
\boldsymbol{B}=\begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22}\end{bmatrix},\ \boldsymbol{\Xi_t}=\begin{bmatrix} u_{1,t} \\ u_{2,t}\end{bmatrix}.
$$

The model is then written in full as:

$$
\begin{aligned}
h_{11,t} &= w_{11}+a_{11}^2u_{1,t-1}^2+a_{21}^2u_{2,t-1}^2+2a_{11}a_{21}u_{1,t-1}u_{2,t-1} \\
&\quad +b_{11}^2h_{11,t-1}+b_{21}^2h_{22,t-1}+2b_{11}b_{21}h_{12,t-1}, \\
h_{22,t} &= w_{22}+a_{12}^2u_{1,t-1}^2+a_{22}^2u_{2,t-1}^2+2a_{12}a_{22}u_{1,t-1}u_{2,t-1} \\
&\quad +b_{12}^2h_{11,t-1}+b_{22}^2h_{22,t-1}+2b_{12}b_{22}h_{12,t-1}, \\
h_{12,t} &= w_{12}+a_{11}a_{12}u_{1,t-1}^2+a_{21}a_{22}u_{2,t-1}^2+(a_{12}a_{21}+a_{11}a_{22})u_{1,t-1}u_{2,t-1} \\
&\quad +b_{11}b_{12}h_{11,t-1}+b_{21}b_{22}h_{22,t-1}+(b_{11}b_{22}+b_{12}b_{21})h_{12,t-1}.
\end{aligned}
$$

With regard to model estimation, the parameters of the multivariate GARCH models for any of the above specifications can be estimated by maximizing the log-likelihood function:

$$
l(\theta)=-\frac{TN}{2}\log 2\pi-\frac{1}{2}\sum_{t=1}^{T}(\log|\boldsymbol{H}_t|+\boldsymbol{\Xi'_t H_t^{-1}\Xi_t}),
$$

where θ denotes all of the unknown parameters to be estimated, N is the number of assets, T is the number of observations, and $\boldsymbol{H_t}$ and $\boldsymbol{\Xi_t}$ are as previously defined.

After deriving the time-varying covariances, $Cov[r_{i,t}, r_{m,t}|\Omega_{t-1}]$, $Cov[r_{i,t}, r_{smb,t}|\Omega_{t-1}]$, and $Cov[r_{i,t}, r_{hml,t}|\Omega_{t-1}]$, from the multivariate GARCH model, we first estimate regressions (5), (6), and (7) using monthly cross-sections. Then, the time-varying prices of risk $\delta_{m,t}$, $\delta_{smb,t}$, and $\delta_{hml,t}$ can be evaluated monthly. If SMB and HML mimic the state variables of Merton's (1973) ICAPM, the covariance risks of $Cov[r_{i,t}, r_{smb,t}|\Omega_{t-1}]$ and $Cov[r_{i,t}, r_{hml,t}|\Omega_{t-1}]$ should be priced. Further, to evaluate the degree of pricing for the risk factors in Models 1 to 4 for periods longer than a month, and to take both cross-sectional and time-series aspects into account, we undertake panel data analysis. By pooling the monthly data on 25 size-ranked portfolios in Japan, we can conduct a balanced panel data analysis in arbitrary time spans. That is, we analyse models (5), (8), (9) and (10) for the entire sample period from January 1982 to December 2003 and for four sub-sample periods using pooled regression. The details of the empirical results are provided in Sections 5 and 6. As argued, the multivariate GARCH model enables us to directly test time-varying risk pricing in the context of Merton's (1973) ICAPM.

4 Data

The sample period of the data analysed in this paper is from January 1982 to December 2003. The individual data series are the risk-free percentage rate, $r_{f,t}$, the market portfolio percentage return, $r_{m,t}$, the Fama–French SMB factor percentage return, $r_{smb,t}$, the Fama–French HML factor percentage return, $r_{hml,t}$, and $r_{i,t}$ are the returns on 25 size-ranked portfolios constructed using the returns of stocks listed on the Tokyo Stock Exchange (TSE) First Section.

In greater detail, $r_{f,t}$ is the gensaki rate from the Japan Securities Dealers Association from January 1982 to May 1984 and the one-month median rate on negotiable-time certificates of deposit (CD) from the Bank of Japan from June 1984 to December 2003.[6] The market return $r_{m,t}$ is the value-weighted return on all stocks in the TSE First Section: this data is provided by the Japan Securities Research Institute (JSRI). The Fama–French SMB and HML factor returns are constructed following the procedures in Fama and French (1993) using the return data of the TSE First Section stocks obtained from the JSRI.[7] We also constructed 25 size-ranked portfolio returns $r_{i,t}$, also following Fama and French (1993).[8]

[6] One-month CD rates are not available before June 1984. Accordingly, following Hamao (1988), we specify the gensaki rate as the risk-free rate before June 1984.

[7] More details of the constructions of SMB and HML in Japan, see Tsuji (2008).

[8] To construct the size-ranked portfolios, all TSE First Section stocks are allocated to one of 25 groups based on their market equity (stock price times shares outstanding) at the end of September of each year t (1981−2003). The value-weighted monthly returns on the portfolios are then calculated from the following October to the next September. Only firms with ordinary common equity are included in our analysis. This means that REITs (Real Estate Investment Trusts) and beneficial interest units are excluded (See also Tsuji (2008).).

Table 1
Sample statistics of the value-weighted returns on 25 portfolios formed on the basis of size: The case in Japan from January 1982 to December 2003

Portfolio	Mean	Median	Std. Dev.	Skewness	Kurtosis
Small	3.663	3.058	10.537	1.047	5.931
Size 2	2.721	2.310	9.006	0.592	4.803
Size 3	2.480	2.108	8.560	0.384	3.538
Size 4	2.017	1.674	8.238	0.312	4.611
Size 5	2.065	1.553	7.794	0.261	3.874
Size 6	1.608	1.422	7.704	0.542	5.356
Size 7	2.118	2.253	8.153	0.905	7.051
Size 8	1.824	1.827	7.556	0.377	4.376
Size 9	1.527	1.951	7.349	0.165	4.154
Size 10	1.761	1.380	7.474	0.255	4.072
Size 11	1.741	1.609	7.238	0.297	4.555
Size 12	1.522	1.537	6.819	0.147	3.806
Size 13	1.532	1.302	6.837	0.072	3.910
Size 14	1.720	1.535	6.906	0.334	4.390
Size 15	1.420	1.833	6.549	0.142	4.828
Size 16	1.519	1.459	6.633	0.072	4.222
Size 17	1.275	0.993	6.510	0.106	4.784
Size 18	1.396	1.296	6.292	0.107	4.717
Size 19	1.480	1.496	5.833	0.251	5.860
Size 20	1.314	1.323	6.131	0.102	4.704
Size 21	1.243	1.304	5.993	0.166	4.715
Size 22	1.367	1.466	5.865	-0.011	4.489
Size 23	1.320	1.257	5.524	0.174	4.594
Size 24	1.233	1.050	5.564	0.216	4.078
Big	0.867	0.867	5.982	0.337	3.721

Notes: The sample statistics of the value-weighted returns of 25 portfolios formed on the basis of size are displayed. The sample period is from January 1982 to December 2003. The size-ranked portfolios are constructed following Fama and French (1993). In constructing the size-ranked portfolios, TSE (Tokyo Stock Exchange) First Section stocks were allocated to 25 groups based on their market equity (stock price times shares outstanding) at the end of September of each year t (1981-2003). Value-weighted monthly returns on the portfolios were then calculated from October to the following September. Only firms with ordinary common equity are included. REITs (Real Estate Investment Trusts) and units of beneficial interest are excluded.

5 Time-varying pricing of market risk and Fama–French factors

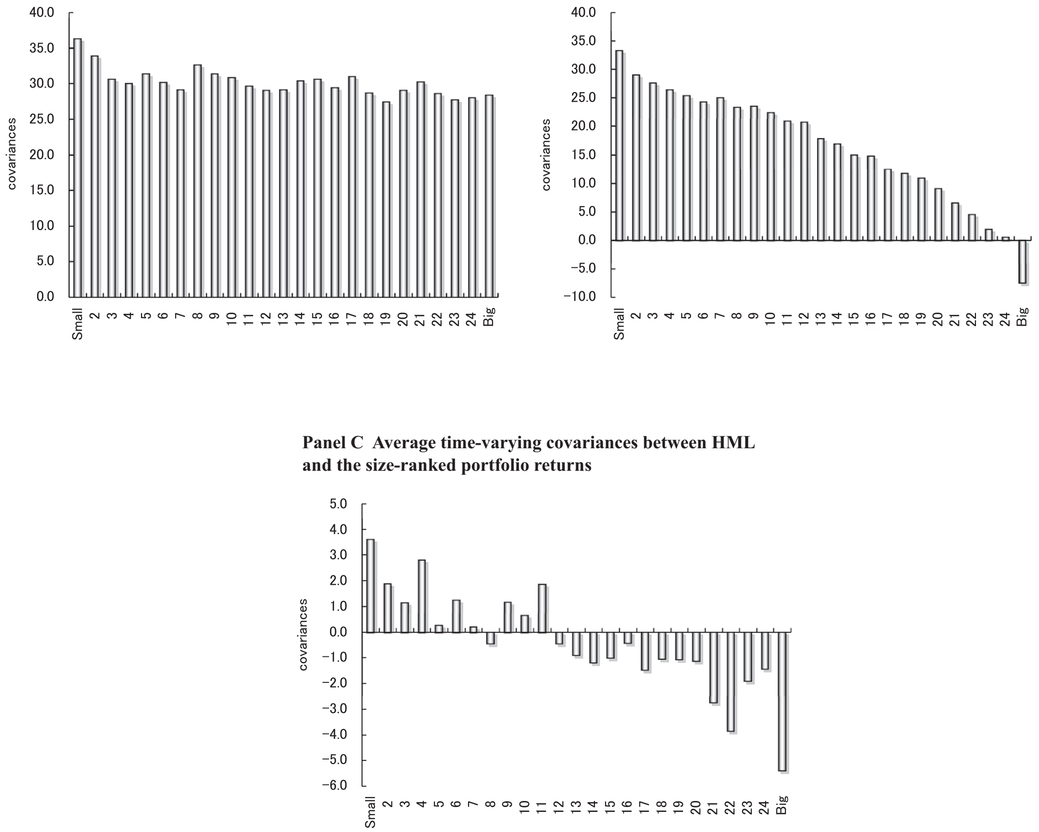
This section provides the empirical results for the pricing of the time-varying covariance risks of the market, SMB, and HML factors. Table 1 provides sample statistics of the value-weighted returns of the 25 size-ranked portfolios over the period from January 1982 to December 2003. The mean returns of the size-ranked portfolios show the rather clear pattern of a monotonic increase from the largest portfolio to the smallest portfolio. This gives clear evidence of a size-effect in Japan. Figure 1 depicts the characteristics of the three covariance risks. From the three graphs in Figure 1, we can see that market covariance risk gradually becomes higher in smaller portfolios (Panel A), SMB covariance risk is clearly higher in smaller portfolios (Panel B), and HML covariance risk is also generally higher in smaller portfolios (Panel C). The increasing pattern of covariance risk is most

Figure 1

Time-varying covariances between market return, SMB, and HML and monthly percentage returns on portfolios formed on size: The case of Japan from January 1982 to December 2003

Panel A Average time-varying covariances between market return and the size-ranked portfolio returns

Panel B Average time-varying covariances between SMB and the size-ranked portfolio returns



distinct for the SMB factor.

Next, applying equations (5), (6), and (7) to the cross-sections, we obtain the monthly time-varying price of risk for the three risk factors in the 25 size-ranked portfolios. Because each regression comprises a cross-section, White's (1980) heteroskedasticity-consistent covariance matrix is used to calculate the p-values. First, Table 2 displays the monthly time-varying price of market risk from January 1982 to December 2003. As shown in Table 2, the price of market risk using the conditional CAPM (5) is generally statistically significant. Statistically significant risk prices with theoretically consistent positive signs (the bold figures in Table 2) are found in 136 of the 264 cases.

Second, Table 3 displays the monthly time-varying price of the SMB covariance risk for the same portfolios and sample period as in Table 2. The observed trends in pricing are very similar to those for market risk: the monthly time-varying price of SMB covariance risk is generally statistically significant, and the number of significant risk prices with positive signs (the bold figures in Table

Table 2
Monthly time-varying price of market risk on 25 portfolios formed on the basis of size: The case of Japan from January 1982 to December 2003

		January	February	March	April	May	June	July	August	September	October	November	December
1982	Risk price	**0.110** **	-0.083 **	-0.094 **	0.036	0.008	0.043	-0.019	-0.125 **	-0.091 **	**0.090** **	**0.314** **	**0.062** **
	p-value	0.000	0.005	0.000	0.127	0.763	0.285	0.432	0.000	0.000	0.010	0.000	0.003
1983	Risk price	**0.138** **	**0.092** **	**0.290** **	**0.242** **	**0.170** **	**0.103** *	**0.312** **	**0.164** **	0.027	**0.066** *	**0.095** **	**0.328** **
	p-value	0.002	0.003	0.000	0.000	0.000	0.017	0.000	0.000	0.343	0.048	0.000	0.000
1984	Risk price	**0.288** **	0.051	**0.248** **	-0.001	-0.274 **	**0.123** **	-0.009	**0.254** **	0.029	**0.231** **	**0.149** **	0.011
	p-value	0.000	0.150	0.000	0.976	0.000	0.000	0.839	0.006	0.214	0.000	0.000	0.626
1985	Risk price	**0.187** **	**0.137** *	**0.083** **	0.013	**0.221** **	**0.154** **	0.002	**0.258** **	**0.187** **	**0.120** **	**0.141** **	**0.102** **
	p-value	0.000	0.021	0.000	0.565	0.000	0.000	0.975	0.000	0.000	0.001	0.001	0.000
1986	Risk price	**0.173** **	**0.410** **	**0.376** **	0.088	**0.149** **	**0.323** **	0.009	0.063	-0.233 **	-0.032	**0.405** **	-0.039 *
	p-value	0.000	0.000	0.000	0.051	0.001	0.000	0.798	0.335	0.009	0.123	0.000	0.029
1987	Risk price	**0.143** **	**0.137** **	**0.070** **	**0.136** **	**0.633** **	**0.143** **	**0.306** **	**0.318** **	**0.086** **	-0.245 **	-0.057 **	-0.026
	p-value	0.000	0.000	0.006	0.000	0.000	0.001	0.005	0.000	0.000	0.009	0.000	0.155
1988	Risk price	**0.446** **	**0.193** **	**0.075** **	**0.242** **	**0.140** **	**0.113** **	-0.123 **	-0.084 **	-0.026	-0.063 **	**0.328** **	**0.062** **
	p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.005	0.248	0.005	0.000	0.002
1989	Risk price	**0.430** **	-0.033	**0.167** **	**0.215** **	**0.177** **	-0.088 **	**0.276** **	**0.107** **	**0.357** **	0.012	**0.211** **	**0.179** **
	p-value	0.000	0.090	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.454	0.000	0.000
1990	Risk price	-0.027	-0.121 **	-0.468 **	-0.101 **	**0.400** **	**0.039** *	0.018	-0.507 **	-0.392 **	**0.260** **	-0.141 **	0.003
	p-value	0.526	0.001	0.000	0.008	0.000	0.017	0.311	0.000	0.000	0.000	0.000	0.574
1991	Risk price	-0.072 **	**0.320** **	**0.036** **	0.003	-0.001	-0.107 **	-0.007	-0.222 **	**0.182** **	**0.086** **	-0.240 **	-0.007
	p-value	0.000	0.000	0.000	0.404	0.795	0.000	0.338	0.000	0.000	0.000	0.000	0.073
1992	Risk price	-0.086 **	-0.040 **	-0.238 **	-0.178 **	**0.184** **	-0.240 **	-0.112 **	**0.233** **	-0.060 **	-0.066 **	**0.064** **	0.004
	p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.776
1993	Risk price	-0.053 **	0.002	**0.507** **	**0.349** **	**0.159** **	-0.130 **	**0.067** **	**0.050** **	-0.075 **	-0.167 **	-0.598 **	**0.101** **
	p-value	0.000	0.816	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	Risk price	**0.326** **	**0.024** **	0.014	**0.079** **	**0.099** **	**0.084** **	-0.053 **	-0.021 *	-0.181 **	0.017	-0.205 **	**0.109** **
	p-value	0.000	0.000	0.313	0.000	0.000	0.000	0.000	0.050	0.000	0.197	0.000	0.000
1995	Risk price	-0.143 **	-0.317 **	-0.121 **	0.015	-0.303 **	-0.128 **	**0.407** **	**0.282** **	-0.010	0.004	**0.191** **	**0.261** **
	p-value	0.000	0.000	0.000	0.052	0.000	0.000	0.000	0.000	0.220	0.651	0.000	0.000
1996	Risk price	**0.195** **	-0.102 **	**0.194** **	**0.302** **	-0.025 *	**0.044** **	-0.349 **	-0.044 **	**0.153** **	-0.157 **	-0.062 **	-0.331 **
	p-value	0.000	0.000	0.000	0.000	0.047	0.006	0.000	0.005	0.000	0.000	0.001	0.000
1997	Risk price	-0.129 **	0.006	-0.121 **	**0.112** **	**0.298** **	**0.074** **	-0.156 **	-0.353 **	-0.307 **	**0.086** *	-0.344 **	-0.388 **
	p-value	0.000	0.657	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.013	0.000	0.000
1998	Risk price	**0.640** **	**0.128** **	-0.050 **	-0.108 **	**0.039** **	**0.110** **	**0.114** **	-0.380 **	-0.149 **	-0.026 *	**0.411** **	-0.142 **
	p-value	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.024	0.000	0.000
1999	Risk price	**0.085** **	**0.035** *	**0.434** **	**0.249** **	-0.014	**0.355** **	**0.070** **	-0.009	0.014	-0.074 **	-0.075	-0.139
	p-value	0.000	0.016	0.000	0.000	0.592	0.000	0.000	0.480	0.507	0.000	0.143	0.053
2000	Risk price	**0.262** **	0.034	**0.255** **	-0.114 **	**0.196** **	**0.694** **	-0.212 **	**0.153** **	-0.065 **	-0.268 **	**0.105** **	-0.139 **
	p-value	0.000	0.343	0.000	0.008	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
2001	Risk price	**0.064** **	**0.101** **	**0.310** **	**0.410** **	-0.077 **	**0.143** **	-0.249 **	-0.048	-0.239 **	**0.198** **	-0.085 **	-0.153 **
	p-value	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.078	0.000	0.000	0.000	0.000
2002	Risk price	-0.064 *	**0.290** **	**0.153** **	**0.136** **	**0.280** **	-0.292 **	-0.054 **	-0.063 **	-0.023	-0.269 **	0.022	-0.127 **
	p-value	0.028	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.056	0.000	0.334	0.000
2003	Risk price	**0.073** *	**0.261** **	**0.059** *	**0.296** **	**0.434** **	**0.532** **	0.049	**0.285** **	**0.137** **	**0.144** **	-0.221 **	**0.159** **
	p-value	0.016	0.000	0.020	0.000	0.000	0.000	0.096	0.000	0.000	0.000	0.000	0.000

Notes: The monthly time-varying price of market risk on 25 size-ranked portfolios is displayed for the sample period from January 1982 to December 2003. The risk price of the conditional CAPM is calculated using the conditional time-varying covariances from a multivariate GARCH model. The portfolios are formed following the procedures in Fama and French (1993). At the end of September of each year t (1981-2003), TSE (Tokyo Stock Exchange) First Section stocks are allocated to one of 25 groups based on their September market equity (stock price times shares outstanding). Value-weighted monthly returns on the portfolios are then calculated from October to the following September. Only firms with ordinary common equity are included. REITs (Real Estate Investment Trusts) and units of beneficial interest are excluded. p-values are calculated using White's (1980) heteroskedasticity consistent covariance matrix. ** and * denotes statistical significance at the 1% and 5% level, respectively. Figures in bold denote statistical significance with a theoretically consistent sign.

3) represent 137 of the 264 cases.

Third, Table 4 presents the monthly time-varying price of the HML covariance risk for the same portfolios and sample period as in Tables 2 and 3. However, the pricing trends are very different from those found for the market and SMB factors. In particular, the monthly time-varying price

Table 3
Monthly time-varying price of risk for the SMB factor on 25 portfolios formed on the basis of size: The case of Japan from January 1982 to December 2003

		January	February	March	April	May	June	July	August	September	October	November	December
1982	Risk price	**0.146** **	-0.020	-0.059	-0.053	0.042	**0.178** **	0.026	-0.242 **	-0.153 **	0.024	**0.264** **	0.020
	p-value	0.001	0.405	0.120	0.053	0.367	0.003	0.583	0.000	0.000	0.664	0.000	0.584
1983	Risk price	**0.227** **	**0.147** **	**0.267** **	**0.427** **	**0.247** **	0.086	**0.673** **	**0.163** **	0.036	**0.198** **	**0.174** **	**0.363** **
	p-value	0.000	0.009	0.000	0.000	0.000	0.238	0.000	0.000	0.616	0.000	0.000	0.000
1984	Risk price	**0.584** **	**0.145** *	0.171	0.044	-0.232 **	**0.155** **	0.309	**0.326** **	0.007	**0.399** **	**0.316** **	-0.023
	p-value	0.000	0.016	0.067	0.082	0.004	0.005	0.234	0.000	0.891	0.000	0.000	0.324
1985	Risk price	**0.246** **	**0.238** *	**0.123** **	**0.093** *	**0.382** **	**0.309** **	**0.193** **	**0.223** **	**0.146** **	**0.140** **	**0.285** **	0.066
	p-value	0.000	0.018	0.004	0.027	0.000	0.000	0.001	0.000	0.000	0.003	0.000	0.093
1986	Risk price	**0.312** **	**0.470** **	**0.258** **	**0.118** **	**0.165** **	**0.283** **	-0.048	-0.072 **	-0.175 **	0.007	**0.171** **	-0.062 **
	p-value	0.000	0.000	0.004	0.006	0.000	0.000	0.129	0.005	0.000	0.354	0.000	0.001
1987	Risk price	**0.103** **	**0.087** **	0.061	0.072	**0.702** **	**0.186** **	**0.333** **	**0.377** **	**0.091** **	-0.251 *	-0.005	0.044
	p-value	0.000	0.000	0.137	0.056	0.000	0.000	0.001	0.000	0.000	0.036	0.902	0.096
1988	Risk price	**0.819** **	**0.337** **	**0.184** **	**0.593** **	**0.334** **	**0.085** **	-0.280 **	-0.027 *	-0.057 **	-0.059 **	**0.345** **	**0.041** *
	p-value	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.043	0.000	0.002	0.000	0.047
1989	Risk price	**0.604** **	-0.053 **	**0.165** **	**0.325** **	**0.304** **	-0.069 **	**0.376** **	**0.340** **	**0.471** **	0.036	**0.284** **	**0.318** **
	p-value	0.000	0.001	0.003	0.000	0.000	0.005	0.000	0.000	0.000	0.097	0.000	0.000
1990	Risk price	**0.146** *	0.024	-0.390 **	-0.422 **	**0.340** **	**0.076** **	**0.079** **	-0.668 **	-0.668 **	**0.805** **	-0.463 **	-0.015
	p-value	0.022	0.573	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.189
1991	Risk price	-0.217 **	**0.633** **	**0.065** **	0.014	0.001	-0.210 **	-0.031	-0.447 **	**0.330** **	**0.211** **	-0.457 **	-0.015
	p-value	0.000	0.000	0.000	0.135	0.932	0.000	0.123	0.000	0.000	0.000	0.000	0.110
1992	Risk price	-0.199 **	-0.071 **	-0.529 **	-0.404 **	**0.292** **	-0.382 **	-0.241 **	**0.390** **	-0.102 *	-0.163 **	**0.116** **	0.068
	p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.027	0.000	0.000	0.069
1993	Risk price	-0.165 **	0.030	**1.125** **	**1.221** **	**0.561** **	-0.120 **	**0.076** **	**0.061** **	-0.145 **	-0.364 **	-0.647 **	**0.139** **
	p-value	0.000	0.134	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	Risk price	**0.668** **	**0.069** **	**0.095** **	**0.192** **	**0.188** **	**0.247** **	-0.094 **	-0.085 **	-0.345 **	0.043	-0.425 **	**0.195** **
	p-value	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.111	0.000	0.000
1995	Risk price	-0.214 **	-0.590 **	-0.232 **	0.016	-0.548 **	-0.196 **	**0.678** **	**0.594** **	-0.049 *	0.029	**0.504** **	**0.542** **
	p-value	0.000	0.000	0.000	0.214	0.000	0.000	0.000	0.000	0.025	0.259	0.000	0.000
1996	Risk price	**0.429** **	-0.210 **	**0.390** **	**0.736** **	-0.021	0.054	-0.676 **	-0.044	**0.263** **	-0.279 **	-0.213 **	-0.484 **
	p-value	0.000	0.000	0.000	0.000	0.451	0.161	0.000	0.194	0.002	0.000	0.000	0.000
1997	Risk price	-0.112 **	-0.001	-0.212 **	**0.081** *	**0.348** **	**0.060** **	-0.298 **	-0.218 **	-0.457 **	**0.067** **	-0.293 **	-0.220 **
	p-value	0.000	0.965	0.000	0.016	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000
1998	Risk price	**0.447** **	**0.058** **	-0.040 **	-0.080 **	**0.026** **	**0.105** **	**0.093** **	-0.370 **	-0.246 **	-0.037 *	**0.680** **	-0.206 **
	p-value	0.000	0.000	0.000	0.000	0.001	0.004	0.002	0.000	0.000	0.028	0.000	0.000
1999	Risk price	**0.127** **	**0.058** *	**0.707** **	**0.628** **	-0.022	**0.821** **	**0.101** **	-0.012	-0.004	-0.148 **	-0.179 **	-0.179 **
	p-value	0.000	0.020	0.000	0.000	0.621	0.000	0.002	0.663	0.923	0.000	0.000	0.000
2000	Risk price	**0.093** **	-0.001	**0.185** **	-0.112 **	**0.163** **	**0.444** **	-0.236 **	**0.200** **	-0.095 **	-0.446 **	**0.136** **	-0.219 **
	p-value	0.000	0.955	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
2001	Risk price	**0.116** **	**0.270** **	**0.406** **	**0.603** **	-0.142 **	**0.303** **	-0.401 **	0.000	-0.391 **	**0.314** **	-0.220 **	-0.258 **
	p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.991	0.000	0.000	0.000	0.000
2002	Risk price	-0.045	**0.545** **	**0.188** **	**0.230** **	**0.523** **	-0.526 **	-0.026	-0.094 *	-0.028	-0.623 **	-0.032	-0.144 **
	p-value	0.231	0.000	0.000	0.000	0.000	0.000	0.367	0.018	0.187	0.000	0.311	0.000
2003	Risk price	**0.261** **	**0.535** **	**0.106** **	**0.470** **	**0.541** **	**0.711** **	**0.057** *	**0.515** **	**0.283** **	**0.265** **	-0.503 **	**0.264** **
	p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.044	0.000	0.000	0.000	0.000	0.000

Notes: The monthly time-varying price of risk for the SMB factor on 25 size-ranked portfolios is displayed for the sample period from January 1982 to December 2003. The risk price is calculated using the conditional time-varying covariances from a multivariate GARCH model. The portfolios are formed following the procedures in Fama and French (1993). At the end of September of each year *t* (1981-2003), TSE (Tokyo Stock Exchange) First Section stocks are allocated to one of 25 groups based on their September market equity (stock price times shares outstanding). Value-weighted monthly returns on the portfolios are then calculated from October to the following September. Only firms with ordinary common equity are included. REITs (Real Estate Investment Trusts) and units of beneficial interest are excluded. *p*-values are calculated using White's (1980) heteroskedasticity consistent covariance matrix. ** and * denotes statistical significance at the 1% and 5% level, respectively. Figures in bold denote statistical significance with a theoretically consistent sign.

of HML covariance risk is less statistically significant than either the market or SMB factors, and the number of statistically significant risk prices with positive signs (the bold figures in Table 4) is equal to only 86 of the 264 cases.

The similarities and differences in the pricing of three types of risk are well presented in Figure 2. This figure provides the degree of year-by-year pricing of the three factors. The yearly values

Table 4
Monthly time-varying price of risk for the HML factor on 25 portfolios formed on the basis of size: The case of Japan from January 1982 to December 2003

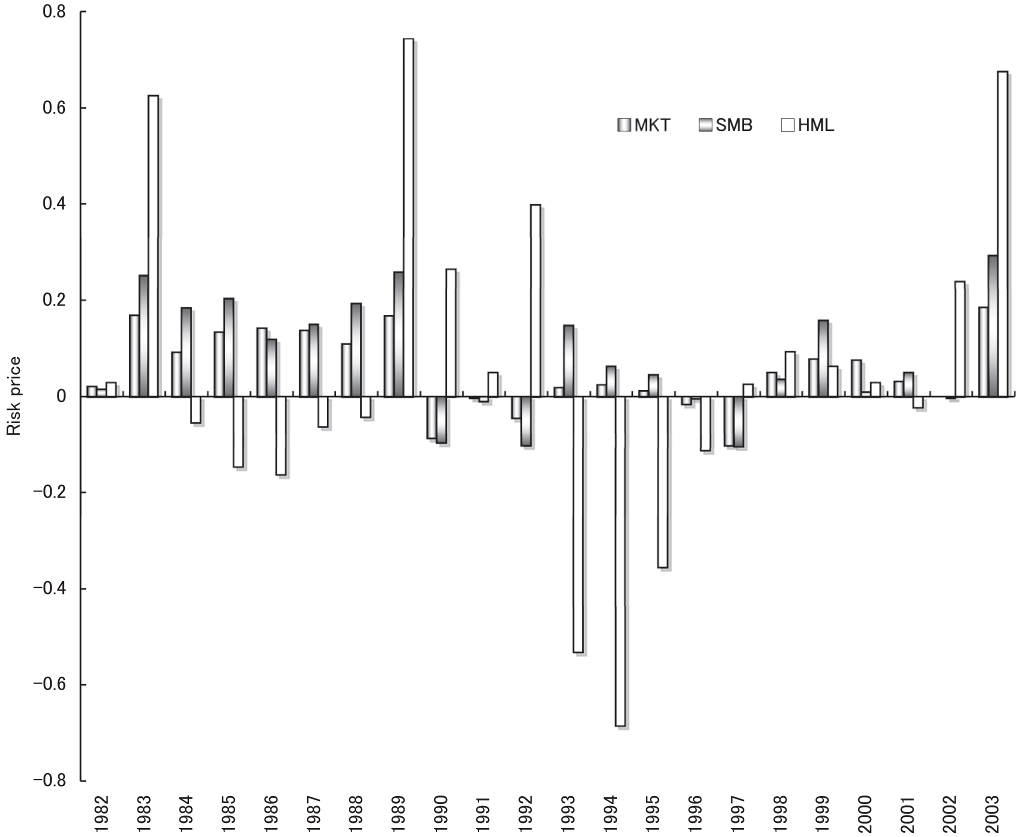
		January		February		March		April		May		June		July		August		September		October		November		December	
1982	Risk price	**0.745**	**	0.187		0.313		-0.709	**	0.005		0.361		-0.224		-0.712	**	-0.389	**	0.470		0.231		0.069	
	p-value	0.009		0.615		0.184		0.001		0.972		0.456		0.260		0.001		0.334		0.059		0.402		0.751	
1983	Risk price	**1.051**	**	0.370		0.508		**2.297**	**	**1.770**	**	0.189		**1.319**	**	-0.515	**	0.042		-0.143		0.159		0.454	
	p-value	0.001		0.308		0.438		0.000		0.000		0.544		0.007		0.001		0.720		0.460		0.434		0.526	
1984	Risk price	-0.341		-0.506	*	-0.264		0.104		**1.734**	**	-0.658	**	**0.567**	*	-0.009		-0.059		-0.738	**	-0.455	**	-0.023	
	p-value	0.670		0.031		0.548		0.448		0.006		0.000		0.022		0.965		0.507		0.000		0.001		0.834	
1985	Risk price	-0.455	**	-0.328	*	-0.269	**	-0.034		-1.137	**	**0.309**	**	**0.332**	**	0.019		-0.083		-0.043		0.017		-0.085	
	p-value	0.000		0.032		0.005		0.772		0.000		0.000		0.001		0.730		0.144		0.615		0.690		0.084	
1986	Risk price	-0.147		-0.446		0.030		0.354		-0.792	**	-0.036		-0.066		0.068		-0.314	*	-0.062		-0.777	**	**0.241**	**
	p-value	0.143		0.098		0.908		0.121		0.000		0.928		0.241		0.505		0.037		0.231		0.005		0.000	
1987	Risk price	-0.471	**	-0.433	**	-0.327	*	-0.545	**	-1.733		**0.803**	**	**1.104**	**	**0.621**	**	**0.296**	**	-0.127		-0.123	**	0.182	
	p-value	0.000		0.000		0.041		0.000		0.057		0.002		0.003		0.000		0.002		0.724		0.002		0.071	
1988	Risk price	0.720		-0.975	**	0.126		0.366		0.963		-0.112		-0.758		**0.148**	*	0.157		0.037		-1.072		-0.106	
	p-value	0.169		0.000		0.443		0.546		0.067		0.769		0.063		0.048		0.254		0.900		0.060		0.599	
1989	Risk price	-1.720		-0.223	*	**1.376**	**	**1.868**	**	**1.496**	**	-0.163		**1.133**	**	**1.212**	**	**2.408**	**	0.498		**1.649**	**	-0.619	
	p-value	0.067		0.020		0.000		0.000		0.000		0.053		0.000		0.000		0.000		0.081		0.000		0.061	
1990	Risk price	0.396		**0.665**	**	**1.256**	*	**0.207**	**	-0.790	**	-0.083	*	-0.008		**1.295**	**	**1.236**	**	-1.292	**	**0.294**	**	-0.008	
	p-value	0.150		0.000		0.016		0.010		0.000		0.020		0.817		0.000		0.000		0.000		0.000		0.562	
1991	Risk price	**0.207**	**	-1.015	**	-0.117	**	-0.021		0.003		**0.555**	**	0.051		**1.240**	**	-1.084	**	-0.446	**	**1.150**	**	**0.068**	*
	p-value	0.000		0.000		0.000		0.191		0.836		0.000		0.116		0.000		0.000		0.000		0.000		0.025	
1992	Risk price	**0.728**	**	**0.307**	**	**3.025**	**	**1.045**	**	-0.596	**	**0.618**	**	**0.341**	**	-0.819	**	**0.206**	**	**0.305**	**	-0.303	**	-0.076	
	p-value	0.000		0.000		0.000		0.000		0.000		0.000		0.000		0.000		0.000		0.000		0.000		0.451	
1993	Risk price	**0.287**	**	-0.008		-6.054	**	**2.404**	**	**1.134**	**	-0.757	**	**0.526**	**	**0.338**	**	-0.561	**	-1.401	**	-1.452		-0.837	*
	p-value	0.000		0.923		0.000		0.000		0.000		0.000		0.000		0.000		0.000		0.000		0.517		0.022	
1994	Risk price	-1.972	*	-0.138	**	-0.148		-0.489	**	-0.872	**	-0.071		-0.067		-0.572	**	-2.043	**	0.350		-3.418	**	1.217	
	p-value	0.021		0.000		0.127		0.000		0.000		0.811		0.542		0.000		0.000		0.506		0.000		0.056	
1995	Risk price	-2.296	**	-1.968	**	-0.483		-0.008		-2.391	**	**1.236**	**	**3.628**	**	-2.177	**	0.043		0.028		-2.490	**	**2.626**	**
	p-value	0.005		0.000		0.171		0.952		0.002		0.001		0.000		0.000		0.471		0.809		0.000		0.000	
1996	Risk price	**1.198**	**	-0.700	**	**1.089**	**	**2.302**	**	-0.094		0.168		-2.178	**	-0.191		**0.988**	**	-1.079	**	-0.578	**	-2.275	**
	p-value	0.000		0.000		0.000		0.000		0.186		0.110		0.000		0.128		0.000		0.000		0.000		0.000	
1997	Risk price	-0.961	**	-0.021		-1.453	**	0.239		**3.676**	**	-0.300	**	**1.112**	**	**2.379**	**	-3.277	**	-0.222		-0.149		-0.727	**
	p-value	0.000		0.912		0.000		0.699		0.000		0.002		0.000		0.000		0.000		0.521		0.891		0.000	
1998	Risk price	**1.319**	**	**0.225**	**	-0.110	**	-0.304	**	**0.107**	**	**0.283**	**	**0.364**	**	-1.299	**	-1.108	**	-0.197		**2.933**	**	-1.095	
	p-value	0.000		0.000		0.000		0.000		0.001		0.001		0.000		0.000		0.000		0.408		0.003		0.071	
1999	Risk price	-0.298		0.328		2.558		-1.605	*	0.018		**1.282**	**	0.145		-0.165		-0.092		-0.642	**	-0.439	**	-0.335	**
	p-value	0.496		0.532		0.280		0.035		0.905		0.003		0.744		0.174		0.703		0.000		0.000		0.000	
2000	Risk price	**0.153**	**	-0.047		**0.233**	**	-0.179	**	**0.353**	**	**0.697**	**	-0.308	**	**0.242**	**	-0.151	**	-0.626	**	-0.110		0.080	
	p-value	0.000		0.145		0.000		0.001		0.000		0.003		0.000		0.001		0.000		0.006		0.594		0.782	
2001	Risk price	-0.334	**	-0.203		0.074		-0.266		-0.221	**	**0.509**	**	-0.704	**	**0.580**	**	**0.479**	**	-0.076		**0.283**	*	-0.393	**
	p-value	0.000		0.397		0.837		0.696		0.000		0.000		0.000		0.001		0.005		0.830		0.026		0.006	
2002	Risk price	**0.365**	*	0.752		**0.547**	**	-0.115		-0.475		-1.189	**	**0.783**	**	**0.471**	**	**0.295**	*	**1.547**	**	-0.294		0.167	
	p-value	0.018		0.146		0.007		0.529		0.237		0.004		0.000		0.000		0.022		0.000		0.125		0.299	
2003	Risk price	0.063		-0.062		**0.430**	**	**1.396**	**	**2.347**	**	**2.772**	**	0.014		**0.672**	**	**0.666**	**	**0.507**	**	-1.289	**	**0.593**	**
	p-value	0.613		0.866		0.000		0.001		0.000		0.000		0.838		0.000		0.000		0.004		0.000		0.000	

Notes: The monthly time-varying price of risk for the HML factor on 25 size-ranked portfolios is displayed for the sample period from January 1982 to December 2003. The risk price is calculated using the conditional time-varying covariances from a multivariate GARCH model. The portfolios are formed following the procedures in Fama and French (1993). At the end of September of each year *t* (1981-2003), TSE (Tokyo Stock Exchange) First Section stocks are allocated to one of 25 groups based on their September market equity (stock price times shares outstanding). Value-weighted monthly returns on the portfolios are then calculated from October to the following September. Only firms with ordinary common equity are included. REITs (Real Estate Investment Trusts) and units of beneficial interest are excluded. *p*-values are calculated using White's (1980) heteroskedasticity consistent covariance matrix. ** and * denotes statistical significance at the 1% and 5% level, respectively. Figures in bold denote statistical significance with a theoretically consistent sign.

are averages of the monthly values of the risk prices. Figure 2 suggests that the pattern of the time-varying pricing of the market and SMB factors is similar because both are priced at a similar time point and with comparable signs. However, the magnitude of pricing for SMB is a little larger than the market factor. While Figure 2 also shows that the pattern of the time-varying pricing between

Figure 2

Yearly average of the time-varying price of risk for the market, SMB, and HML factors on 25 portfolios formed on the basis of size: The case of Japan from January 1982 to December 2003



HML and either the market factor or SMB differs, both the timing and magnitude of pricing are very different between HML and either the market or SMB. It is also interesting that the results in Tables 2, 3, 4 suggest that from a risk pricing viewpoint, the conditional CAPM generally demonstrates better performance than that suggested by Chen et al. (1986), Hamao (1988), and Fama and French (2006), amongst others.

Next, we further compare the pricing of each risk by implementing the panel data analysis. Table 5 presents the results. First describing the results for market risk, this is shown to be well priced in all periods except for Model 2 in the sub period January 1987 to December 1992 (Panel C). Second, for the SMB covariance risk, this is also well priced in all periods except for Models 2 and 4 in the sub period January 1993 to December 1998 (Panel D). Thus, we appreciate that the market and SMB covariance risks are also well priced in the panel data analysis. Third, regarding the HML covariance risk, this is also well priced except for Models 3 and 4 in the sub period from January 1982 to December 1986 (Panel B) and Models 3 and 4 in the sub period from January 1999 to December 2003 (Panel E). Thus, we can again see that the pricing of HML is different from the

Table 5
Panel data analysis of the time-varying price of risk on 25 portfolios formed on the basis of size: The case of Japan from January 1982 to December 2003

	Market risk price	*p*-value	Risk price of SMB	*p*-value	Risk price of HML	*p*-value
Panel A From January 1982 to December 2003						
Model 1	**0.0361** **	0.0000				
Model 2	**0.0209** **	0.0000	**0.0306** **	0.0000		
Model 3	**0.0419** **	0.0000			**0.0972** **	0.0000
Model 4	**0.0354** **	0.0000	**0.0119** *	0.0332	**0.0879** **	0.0000
Panel B From January 1982 to December 1986						
Model 1	**0.1017** **	0.0000				
Model 2	**0.0884** **	0.0000	**0.0270** **	0.0003		
Model 3	**0.1016** **	0.0000			-0.0018	0.9264
Model 4	**0.0879** **	0.0000	**0.0273** **	0.0003	-0.0082	0.6729
Panel C From January 1987 to December 1992						
Model 1	**0.0142** **	0.0017				
Model 2	-0.0258 **	0.0002	**0.1005** **	0.0000		
Model 3	**0.0622** **	0.0000			**0.2411** **	0.0000
Model 4	**0.0254** **	0.0027	**0.0823** **	0.0000	**0.2205** **	0.0000
Panel D From January 1993 to December 1998						
Model 1	**0.0276** **	0.0000				
Model 2	**0.0364** **	0.0000	-0.0137	0.1315		
Model 3	**0.0223** **	0.0001			**0.0727** **	0.0070
Model 4	**0.0432** **	0.0000	-0.0404 **	0.0002	**0.1407** **	0.0000
Panel E From January 1999 to December 2003						
Model 1	**0.0696** **	0.0000				
Model 2	**0.0496** **	0.0000	**0.0379** **	0.0013		
Model 3	**0.0698** **	0.0000			-0.0024	0.8989
Model 4	**0.0375** **	0.0001	**0.0720** **	0.0000	-0.0818 **	0.0016

Notes: Four asset pricing models are evaluated using the panel data analysis. ** and * attached to the coefficients denotes the values are significant at the 1% and 5% level, respectively. Model 1 is $E[(r_{i,t}-r_{f,t}) \mid \Omega_{t-1}] = \delta_{m,t} Cov[r_{i,t}, r_{m,t} \mid \Omega_{t-1}]$; Model 2 is $E[(r_{i,t}-r_{f,t}) \mid \Omega_{t-1}] = \delta_{m,t} Cov[r_{i,t}, r_{m,t} \mid \Omega_{t-1}] + \delta_{smb,t} Cov[r_{i,t}, r_{smb,t} \mid \Omega_{t-1}]$; Model 3 is $E[(r_{i,t}-r_{f,t}) \mid \Omega_{t-1}] = \delta_{m,t} Cov[r_{i,t}, r_{m,t} \mid \Omega_{t-1}] + \delta_{hml,t} Cov[r_{i,t}, r_{hml,t} \mid \Omega_{t-1}]$; Model 4 is $E[(r_{i,t}-r_{f,t}) \mid \Omega_{t-1}] = \delta_{m,t} Cov[r_{i,t}, r_{m,t} \mid \Omega_{t-1}] + \delta_{smb,t} Cov[r_{i,t}, r_{smb,t} \mid \Omega_{t-1}] + \delta_{hml,t} Cov[r_{i,t}, r_{hml,t} \mid \Omega_{t-1}]$. The periods tested are the whole sample period of January 1982 to December 2003 and four sub-sample periods. All conditional time-varying covariances used in the tests are derived from the multivariate GARCH model. Figures in bold denote that the values are statistically significant with theoretically consistent signs.

market factor and SMB in the panel data analysis. However, HML covariance risk is as generally well priced as the market and SMB covariance risks in the ICAPM framework. On the basis of these pricing results, we believe that SMB and HML mimic the state variables in Merton's (1973) ICAPM as suggested by Fama and French (1996).

6 Comparisons of the conditional asset pricing models

In this section, we compare and more formally evaluate the empirical performance of the four conditional asset pricing models: namely, (5), (8), (9) and (10). By doing so, we attempt to judge the pricing degree of the SMB and HML covariance risks more formally in the context of the ICAPM.

More specifically, we perform F-tests using the F-test statistic in (12). We compare the four models with five tests as follows: Test 1: Model 1 versus Model 2 (null hypothesis H_0 is $\delta_{smb,t} = 0$), Test 2: Model 1 versus Model 3 (null hypothesis H_0 is $\delta_{hml,t} = 0$), Test 3: Model 2 versus Model 4 (null hypothesis H_0 is $\delta_{hml,t} = 0$), Test 4: Model 3 versus Model 4 (null hypothesis H_0 is $\delta_{smb,t} = 0$), and Test 5: Model 1 versus Model 4 (null hypothesis H_0 is $\delta_{smb,t} = 0$ and $\delta_{hml,t} = 0$). Since these are nested tests, under the null hypothesis the F-statistic (12) follows the F-distribution with degrees of freedom r and $nT - k$ (Maddala, 1992).

$$F = \frac{(RRSS - URSS)/r}{URSS/(nT - k)}, \tag{12}$$

where $RRSS$ is the sum of squared residuals of the restricted model, $URSS$ is the sum of squared residuals of the unrestricted model, r is the number of restrictions, n is the number of samples in each month, T is the number of months in the test period, and k is the number of explanatory variables in the unrestricted model.

We now describe the results shown in Table 6 in order. First, in Test 1 Model 1 is not rejected against Model 2 except for the sub period from January 1987 to December 1992 (Panel C). Second, in Test 2 Model 1 is rejected against Model 3 for the whole sample period (Panel A) and for the sub period from January 1987 to December 1992 (Panel C). The results for Tests 1 and 2 imply that HML adds explanatory power to Model 1, while SMB does not add explanatory power to Model 1.

Third, in Test 3 Model 2 is rejected against Model 4 for the whole sample period (Panel A) and for the sub period from January 1987 to December 1992 (Panel C). Fourth, in Test 4 Model 3 is not rejected against Model 4 except for the sub period from January 1987 to December 1992 (Panel C). The results in Tests 3 and 4 are similar to Tests 1 and 2: namely, Tests 3 and 4 indicate that HML adds explanatory power to Model 2, while SMB does not add explanatory power to Model 3. However, taking into consideration the strong monthly pricing of SMB shown in Table 3, we argue that the weak contribution of SMB in Models 2 and 4 is not because of the weak pricing of SMB itself, rather the similar pricing pattern of the market factor and SMB first shown in Figure 2. On the other hand, because the pricing pattern differs for market and HML, as also shown in Figure 2, we consider that HML contributes well to Models 3 and 4.

Finally, in Test 5, Model 1 is rejected against Model 4 except for the sub period from January 1982 to December 1986 in Panel B. Therefore, we consider the conditional Fama–French model, constructed by incorporating the time-varying risk of SMB and HML in Merton's (1973) ICAPM, is a better pricing model than the simple conditional CAPM. Therefore, as the above evidence demonstrates, SMB and HML are priced and contribute to improvements in the ICAPM model. Consequently, SMB and HML mimic state variables in Merton's (1973) ICAPM as Fama and French (1996) insisted.

Table 6
Panel data F-tests for model evaluation using 25 portfolios formed on the basis of size: The case of Japan from January 1982 to December 2003

Test 1		Test 2		Test 3		Test 4		Test 5	
Model 1 versus Model 2		Model 1 versus Model 3		Model 2 versus Model 4		Model 3 versus Model 4		Model 1 versus Model 4	
H_0: $\delta_{smb,t} = 0$ (Model 1 holds)		H_0: $\delta_{hml,t} = 0$ (Model 1 holds)		H_0: $\delta_{hml,t} = 0$ (Model 2 holds)		H_0: $\delta_{smb,t} = 0$ (Model 3 holds)		H_0: $\delta_{smb,t} = 0$ and $\delta_{hml,t} = 0$ (Model 1 holds)	
F-statistic	p-value	F-statistic	p-value	F-statistic	p-value	F-statistic	p-value	F-statistic	p-value
Panel A From January 1982 to December 2003									
1.4038	0.0871	3.8724 **	0.0000	2.6273 **	0.0000	0.1795	1.0000	8.0795 **	0.0000
Panel B From January 1982 to December 1986									
0.5025	0.9810	0.0003	1.0000	0.0068	1.0000	0.5004	0.9815	1.0014	0.4720
Panel C From January 1987 to December 1992									
2.3025 **	0.0003	4.4966 **	0.0000	3.7104 **	0.0000	1.5689 *	0.0365	12.2040 **	0.0000
Panel D From January 1993 to December 1998									
0.0886	1.0000	0.2840	0.9998	0.7189	0.8424	0.5251	0.9744	1.6143 **	0.0045
Panel E From January 1999 to December 2003									
0.4016	0.9964	0.0006	1.0000	0.3787	0.9978	0.7754	0.7771	1.5520 **	0.0087

Notes: F-tests are performed for model evaluation using the panel data analysis. ** and * attached to the F-statistic denotes that the null hypothesis is rejected at the 1% and 5% level of statistical significance, respectively. In Test 1, the null hypothesis is H_0: $\delta_{smb,t} = 0$ and the alternative hypothesis is H_1: $\delta_{smb,t} \neq 0$ in Model 2: $E[(r_{i,t}-r_{f,t}) \mid \Omega_{t-1}] = \delta_{m,t} Cov[r_{i,t}, r_{m,t} \mid \Omega_{t-1}] + \delta_{smb,t} Cov[r_{i,t}, r_{smb,t} \mid \Omega_{t-1}]$. When H_0 is rejected, Model 2 is supported against Model 1. In Test 2, the null hypothesis is H_0: $\delta_{hml,t} = 0$ and the alternative hypothesis is H_1: $\delta_{hml,t} \neq 0$ in Model 3: $E[(r_{i,t}-r_{f,t}) \mid \Omega_{t-1}] = \delta_{m,t} Cov[r_{i,t}, r_{m,t} \mid \Omega_{t-1}] + \delta_{hml,t} Cov[r_{i,t}, r_{hml,t} \mid \Omega_{t-1}]$. When H_0 is rejected, Model 3 is supported against Model 1. In Test 3, the null hypothesis is H_0: $\delta_{hml,t} = 0$ and the alternative hypothesis is H_1: $\delta_{hml,t} \neq 0$ in Model 4: $E[(r_{i,t}-r_{f,t}) \mid \Omega_{t-1}] = \delta_{m,t} Cov[r_{i,t}, r_{m,t} \mid \Omega_{t-1}] + \delta_{smb,t} Cov[r_{i,t}, r_{smb,t} \mid \Omega_{t-1}] + \delta_{hml,t} Cov[r_{i,t}, r_{hml,t} \mid \Omega_{t-1}]$. When H_0 is rejected, Model 4 is supported against Model 2. In Test 4, the null hypothesis is H_0: $\delta_{smb,t} = 0$ and the alternative hypothesis is H_1: $\delta_{smb,t} \neq 0$ in Model 4: $E[(r_{i,t}-r_{f,t}) \mid \Omega_{t-1}] = \delta_{m,t} Cov[r_{i,t}, r_{m,t} \mid \Omega_{t-1}] + \delta_{smb,t} Cov[r_{i,t}, r_{smb,t} \mid \Omega_{t-1}] + \delta_{hml,t} Cov[r_{i,t}, r_{hml,t} \mid \Omega_{t-1}]$. When H_0 is rejected, Model 4 is supported against Model 3. In Test 5, the null hypothesis is H_0: $\delta_{smb,t} = 0$ and $\delta_{hml,t} = 0$, and the alternative hypothesis is H_1: $\delta_{smb,t} \neq 0$ and $\delta_{hml,t} \neq 0$ in Model 4: $E[(r_{i,t}-r_{f,t}) \mid \Omega_{t-1}] = \delta_{m,t} Cov[r_{i,t}, r_{m,t} \mid \Omega_{t-1}] + \delta_{smb,t} Cov[r_{i,t}, r_{smb,t} \mid \Omega_{t-1}] + \delta_{hml,t} Cov[r_{i,t}, r_{hml,t} \mid \Omega_{t-1}]$. When H_0 is rejected, Model 4 is supported against Model 1. The tests are performed for the entire sample period from January 1982 to December 2003 and for the four sub-sample periods. All conditional time-varying covariances used in the tests are derived from the multivariate GARCH model.

7 Conclusions

This paper investigated whether Fama–French factors, as suggested by Fama and French (1996), mimic state variables in Merton's (1973) ICAPM framework. To test this particular interpretation of the Fama–French factors, we examined the degree of pricing of the market, SMB, and HML covariance risks for the Japanese stock market in the context of Merton's (1973) ICAPM, while taking the time-varying characteristic of risk prices into account. Our conclusions on Fama and French's (1996) suggestion are summarized as follows.

- First, both our monthly and panel data analysis of time-varying risk pricing reveals that the SMB factor is well priced in the context of Merton's (1973) ICAPM. This provides supportive evidence for Fama and French's (1996) suggestion.
- Second, both our monthly and panel data analysis of time-varying risk pricing also finds that the HML factor is generally priced in the framework of Merton's (1973) ICAPM although the degree of pricing is a little weaker than the SMB factor. This finding also supports Fama and French's (1996) suggestion.
- Third, from the viewpoint of model evaluation using formal F-tests, the conditional CAPM is rejected against the conditional Fama–French model. This suggests that the conditional Fama–French model is superior to the conditional CAPM. This finding again supports Fama and French's (1996) suggestion.

In addition, in the process of our analysis, and as an ancillary result, we find that the conditional covariance market risk in the CAPM derived with a multivariate GARCH model is generally strongly priced in Japan. This finding is interesting because in many studies the simple CAPM is very often refuted.

Furthermore, from a technical point of view, our paper has several noteworthy characteristics. These include: (1) a detailed examination of risk pricing and model evaluation; (2) the incorporation of both time-varying risks and the time-varying price of risk in the ICAPM; (3) consideration of both time-series and cross-sectional aspects in panel data analysis when evaluating the ICAPM; (4) the implementation of more direct tests of the effectiveness of the time-varying covariance risk using a multivariate GARCH model.

We consider that these technically advanced aspects of our approach enable more direct and detailed tests of Fama and French's (1996) suggestion. As a result, we obtain evidence in Japan that supports Fama and French's (1996) assertion that SMB and HML mimic the state variables in Merton's (1973) ICAPM. Nevertheless, international research along similar lines of inquiry is still required.

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